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N.D. Zavalov, V.A. Ponamarenko

THE ACTIVITY OF COSMONAUTS

'Translation of: "Deyatel'nost' Kosmonavta," Material for Chapter 4, Volume 2, Part 4 of the work: Osnovy Kosmicheskoy Biologii i Meditsiny /Foundations of Space Biology and Medicine/, Moscow, Academy of Sciences of the USSR, 1970, 160 pages.

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N. D. Zavalova and V. A. Ponomarenko

ABSTRACT: The problems faced by cosmonauts in space are unique in many respects. Isolation, prolonged inactivity, the need to be constantly alert, weightlessness - all of these factors create frequently unusual sensations and illusions which can be dangerous if the cosmonaut does not recognize the problem and deal adequately with it. The work contains abstracts of numerous Soviet papers on spacecraft simulator experiments involving isolation, hypokinesia, and other stressful situations.

Section 1 - General Characteristics of the Conditions and Features of Activity of Cosmonauts

/1*

The characteristics of specific conditions of activity of cosmonauts are given in [14, 15, 75 -- see pages 2-7]. The most specific factor for space is the postural factor, a general shortage of afferentation and isolation. These factors produce complexity of spatial perception, difficulty in coordination of movement, decrease in psychological preparedness for emergency action, and a decrease in motivation. Other factors mentioned in [19, 24] including danger, hypokinesia, lack of time, necessity of performing the function of an operator of a control system are more or less characteristic of the activity of operators in general, and particularly for a pilot in automated flight.

The general characteristics of the activity of the operator of a control system are given in [37, 38, 59, 62, 68]. The important characteristics of this activity are indicated by the increase in the relative importance of

*Numbers in the margin indicate pagination in the foreign text.

higher psychic functions, an increase in the feeling of responsibility, and also the fact that activity with an immediate object of control is replaced by activity with informational models. There is an increase in the complexity of activity on the one hand and a rise in the cost of error on the part of the operator on the other.

The most important specific feature of the human operator is the fact that man must be active in order to be able to retain his working ability and to be able to function effectively in general. The deprivation of man of the possibility to act during a certain period of time and the possibility of experience does not allow keeping him "in complete order" (page 19).

The latter position of scientific psychology is of the greatest significance for the activity of cosmonauts and in particular for the solution of the problem of distribution of functions between automation and man in the process of controlling the craft. /2

References which give the general characteristics of the activity of cosmonauts are listed on pages 2-23.

Gorbov, F. D.: *Kosmicheskaya Psikhologiya. Kosmicheskaya Biologiya i Meditsina. Mediko-Biologicheskiye Problemy Kosmicheskikh Poletov*, [Space Psychology. Space Biology and Medicine. Medical-Biological Problems of Space Flights]. Moscow, "Nauka" Press, 1966, p. 392-400.

Two problems of space psychology are discussed: the psychology of speed and ecological psychology. Mention is made of the intensification of labor during rapid movement of an object in space, inasmuch as under these conditions it is necessary to work continuously even with automatic control; to observe the required order of activity; to carry out functions with a lack of time; to perform an estimate of the effect of working indirectly. Mention is made of the postural factor associated with such influences as a change in the position of the area of support, absence of an area of support (weightlessness, etc.). Difficult states may arise under the combined action of these factors.

The continuity factor causes the development of plans of foresight, a method of construction of an action and its result. These systems of /3

forecasting are a particularly sensitive and vulnerable point. In formulating the forecasting system, the prompting of the required effect may lead to an erroneous effect.

The kinetic function becomes more complicated in the activity of the cosmonaut. Difficult states associated with the feeling of instability may lead to the development of erroneous sensations.

Problems of ecological psychology in space are associated with separation from the Earth and isolation. Difficult states in isolation are associated with an insufficiently high level of wakefulness and an insufficient ability to remain in a state of expectation and readiness for a long period of time.

In conclusion, the problems of group psychology are discussed.

Bibliography of 10 items.

Gorbov, F. D.: "Some Problems of Space Psychology," *Voprosy Psikhologii*, No. 6, p. 3-13, 1962.

The primary importance of examining the career history of the cosmonaut as well as the similarity of many working operations for the pilot and cosmonaut are pointed out.

Aspects of the activity of the pilot and cosmonaut which are common to both and are of considerable significance are the following:

- continuous activity;
- necessary (required) order of operations;
- lack of time;
- certain sequential nature of perception for purposes of evaluation of the useful effect of work and its results;
- the postural factor, which combines such effects as change in position of the area of support (in weightlessness), loss of area of support, which sometimes develops in certain maneuvers; /4
- the postural factor is related to the development of neuro-psychic stress, disruption of spatial perception;
- the novelty factor.

A characteristic feature is the fact that a continuous pattern of activity is provided by a continuous influx of information including that information which is received as the result of his own activity, so that a rapid and insignificant event in flight may become an important and significant event. Under the novel conditions in which new interactions develop between the operative activity and the signal information, it is possible for states to develop which are difficult in the psychological sense. In this regard, mention could be made of such a specific factor as a general shortage of afferentation, as well as those difficult states which develop when useful information is perceived against a background of noise, especially when the noise includes the useful signals themselves with insufficient correcting and supporting information in the course of transmission. The methods of "reproduction" and psychological modelling as methods of psychological selection of cosmonauts are described.

Mention is made of the possibility of "modelling the future" as a method of advancing future working ability of the cosmonaut. A number of tests are described based on the principle of reproduction, for example, "reproduction of an episodic event in associative, oral and material experiment." It is pointed out that practical use of this method requires recording of EEG, EKG, EMG and SGR parameters as well as magnetic tape recordings.

One of the methods which makes it possible to evaluate the capacity for /5
precise performance of specific operative activity under conditions of increased, decreased and altered afferentation is described; it is the method of determining the "noise resistance". Mention is made of the necessity for inducing an understanding of noise sensitivity of man in conjunction with his participation in the control of automatic devices, as well as in all forms of activity where the "useful" information which reaches the individual may be distorted due to error or defects in the operation of indicators and especially in cases when the activity is accompanied by voice communication.

The concept of noise resistance does not include all cases of influence on the activity by external stimuli, capable of affecting the course of performance of work, but only the confusing effect of correcting and prompting reports during their intrusion into the working scheme of forecasting.

To determine the noise resistance, a numerical table was used, having numbers in two colors, by which it was proposed through alternation of the colors to count the numbers in one color in ascending order, and the numbers in the other color in decreasing order, pointing out these numbers.

Recording of the physiological functions made it possible to isolate not only the moments of realized responses (erroneous and correct) as well as those responses which were noted but restrained at the last moment. The difficulty was caused both by the number of these values but also by the different color (number-noise), as well as the prompting of the numbers orally with a tape recording. The noise resistance develops as an independent /6
quality in man, consisting in the ability to accomplish an active selection by carrying out precise differentiation under conditions of exposure to the influence of stimuli that are similar to those which must be differentiated.

Parin, V. V. and F. D. Gorbov: "Experimental Studies in Space Psychophysiology," *Kosmicheskaya Biologiya i Meditsina*, Vol. 1, No. 1, pp. 7-12, 1967.

The article is a paper delivered at the 18th International Congress of Psychologists (Moscow, August 1966). The article describes methods of examining candidates in the selection of cosmonauts. The basis of the methods is the idea of testing the resistance of "given operative activity", which is tested with respect to three types of stimuli: 1) extremal physical flight factors; 2) remote stimuli with unexpected strong action; 3) specific (psychologically difficult) stimuli -- noises similar to the useful signal.

The principal criteria for evaluating the results are not only the criteria for the quality of activity but the criteria of the resistance of the physiological indices. Only the development of signs of physiological discomfort with a sharp drop in working ability was rated as a negative indication. Evaluation of the effectiveness of activity was performed in order to reveal the development of significant difficulties in the course of work.

The authors feel that the most necessary qualities for a cosmonaut are adaptability and learning ability, with behavioral adaptability being most important.

The following are mentioned as causes of difficulty in adaptation of behavioral systems: /7

- novelty of the situation in which the required movements are carried out with changes in the "behavior" of the subjects;
- complexity of spatial perception, related to newly recognized activity of postural musculature, tonic conditions and support reflexes, hence the complexity of accomplishing sensory correction under conditions of weightlessness;
- simultaneous and independent alteration of accustomed affarentation, whence the importance of the role of preliminary "internal replay" of future activities in the formation of systems of anticipation.

Mention is made of the role of motivation and mutual compatibility of the crew for solving problems of sensory deprivation and isolation.

In conclusion, the importance of evaluating the real activity of the cosmonaut for developing optimum work and rest regimes is discussed, as well as for transferring the experience of a cosmonaut who has completed a flight to his comrades who are preparing for one.

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Alyakrinskiy, B. S.: "Paths of Development of Space Psychology," *Kosmicheskaya Biologiya i Meditsina*, Vol. 1, No. 2, pp. 14-21, 1967.

The paper deals with the general problems of space psychology. Mention is made of the advantages of human beings over robots, including the ability of functioning productively in unexpectedly complicated situations. Mention is made of a number of specific factors in space flight which govern the problematics of space psychology.

The factor of inactivation of the subjects hampers their working ability. /8 According to the data of S. G. Zharov and A. P. Kuz'minov, a stay of 12 days in a model of a spacecraft led to a decrease in accuracy of orientation of the craft with an increase in the time required for data transmission by 10%.

Under the influence of weightlessness (in flight along a ballistic curve), according to the data of A. T. Zverev, et al., all motor reactions are prolonged and lose their normal accuracy.

With sensory impoverishment, according to the data of N. A. Agadzhanyan, F. D. Gorbov, L. A. Sivokon', et al., mental working ability was found to decrease in laboratory experiments.

The author feels the majority of space flight factors can be simulated on Earth in order to study the reactions of man to flight conditions. An exception is the problem of psychic reactions of man to danger. Production of situations of real danger is possible in the course of parachute training, but even then it is done by imitation of emergency conditions.

Bibliography of 41 items.

Gurovskiy, N. N.: *Nekotoryye Osobennosti Trudovy Deyatel'nosti Kosmonavtov v Dlitel'nom Kosmicheskom Polet, Ocherki Psikhofiziologii Truda Kosmonavtov,* [Some Characteristics of the Work Activity of Cosmonauts on a Long Space Flight. Outlines of Psychophysiology of the Work of Cosmonauts]. Moscow, "Meditsina" Press, 1967, pp. 5-13.

The book deals with the characteristics of the conditions of activity of cosmonauts and the principal forms of activity in a general fashion. Mention is made of the characteristics of developing a high activity of perception, attention with absence of intensive muscular actions and the necessity for maintaining constant readiness for activity in an unexpected situation against the background of hypokinesia. The activity of the cosmonaut is compared with the work of an operator of an automated system. Attention is drawn to the complexity of the work of the cosmonaut during the docking of two spacecraft, during landing or maneuvering along the flight path.

Special emphasis is placed on the fact that a specific feature of the work of a cosmonaut consists in "activity with a delayed ending", i.e., the fact that the working process of the cosmonaut is a process which is poorly correlated by feedback. Mention is also made of such characteristics of the situation as monotony, weightlessness, and limitation of cabin size.

Denisov, V. G., Kuz'minov, A. P. and V. I. Yazdovskiy: "Principal Problems of Engineering Psychology of Space Flight," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology]. Moscow, "Nauka" Press, 1964, Vol. III, pp. 66-79.

The articles discusses problems of engineering psychology in the design of spacecraft. (1) Study of the psychophysiological capacities of man, when included in the control system. (2) Development of recommendations for the construction of control systems which are rational from the standpoint of a human operator. (3) Study of methods and means of preparing man for activity in a control system for spacecraft.

The article mentions the specificity of the conditions in which the activity of the cosmonaut must take place; the authors discuss concrete problems of studying the psychophysiological possibilities of man. These /10 include: investigation of the interaction of analyzers, study of motor acts during control, explanation of the differences between functional possibilities of man on Earth and in space flight. Mention is made of the need for designing systems for monitoring the study of dynamic properties of man and describing the elements of his participation in control in the terms and symbols of automatic regulation. The authors feel that they have found the transmission functions of operators which correspond to the stationary linear branch and which consider only one nonlinearity in the form of a constant delay, but that there is still a need to conduct experimental studies of the transmission function which is valid for a concrete system and working conditions. The authors feel that the principal functions of a cosmonaut in flight are the functions of compensating tracking and the function of observation and control and that in order to have an optimum combination of man with automation it is necessary to study the principles of distribution of functions between the cosmonaut and the systems of the craft. It is mentioned that even in the case of complete automation of the control processes it is necessary to take into account the possibility of the craft being controlled by a human being, inasmuch as he must play the role of complexes of reliably duplicated branches of the automatic mechanism. It is emphasized that this

sort of participation of a human being in the function of automatic devices increases the reliability of these systems and the brief inclusion of a human being in control during correction of the flight trajectory considerably simplifies the requirements placed on the automatic machinery.

Mention is also made of one of the more important problems, namely the determination of the capacities of the cosmonaut as far as perception and analysis of information are concerned. The impossibility of using these criteria for evaluation of the quality of information which is analyzed in information theory is confirmed. /11

The necessity of distributing the functions for analysis of information between the man and machine is emphasized, as is the importance of determining the degree to which the problem of analyzing the information must be solved by machines and the degree to which completion of the solution is to be carried out by a human being. It is mentioned that possibilities of a human operator as far as detection and analysis of information depend on how well the functional characteristics of the operator are matched with the means of representing the information.

The problem of using electrophysiological methods of investigation for evaluating working capacity is raised.

Investigation on simulators is suggested as a method of examining the characteristics of the cosmonaut as a living branch of the control system.

Zinchenko, V. P., A. N. Leont'yev and D. Yu. Panov: "Problems of Engineering Psychology," in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology]. Moscow, Moscow State University Press, 1964, pp. 5-23.

The article deals with the basic outlines of the activity of man in conjunction with automation of work processes. It has been pointed out that the most specific feature of the activity of the operator in an automated system is the fact that the operator lacks the ability to observe directly the objects which he is controlling and is required to utilize information which is supplied to him through communication channels. Activity with real objects is replaced by activity with information models. The following determination

of an information model is given: "data which travel along communication channels from objects under control and which characterize the state of an external medium and of the control system itself, and their representation on certain devices form that which we shall call information models of these objects." /12

It is pointed out that in conjunction with the successes of automation, the internal psychic functions of man during labor have been advanced to the first level, primarily the sensory and mental functions.

Bibliography of 13 items.

Zinchenko, P. I. and V. P. Zinchenko: "Study of Memory in Conjunction With Problems of Engineering Psychology," in the book: *Problemy Inzhenernoy Psikhologii. Psikhologiya Pamyati*, [Problems of Engineering Psychology. Psychology of Memory]. Leningrad, 3rd Edition, 1965, pp. 3-18.

The most important feature of the activity of the operator in an automated system is the fact that this activity is accomplished not with real objects but with their information models. To analyze the requirements for construction of informational models, it is necessary to take into account the functional characteristics of the operator, particularly the characteristics of the flow of processes of perception, memory, thinking during performance of corresponding actions. There are two basic types of activity of the operator with information models: an information search with rapid execution and informational search with delayed execution. The first type is characterized by a small amount of information which may be detected and evaluated so rapidly that the information search is practically nonexistent. The solution is /13 adopted on the basis of simple rules and does not require consideration of a great many variables. The operator immediately proceeds from perception to the executive action. This type of activity places the greatest requirements on long-term memory. The second type of activity is characterized by the presence of a great deal of information and the process of its perception is converted into an independent act which proceeds with time; the process of information searching is rather complex and execution begins with a delay. This type of activity, which places an equal demand on long-term memory, also poses

very high demands on the operator memory; detection of objects, required in execution, precedes organization of information obtained following decoding regarding the objects under control into an integral system of interrelated characteristics. Perception and evaluation of the situation, preceding the adoption of a solution, is nothing more than the determination and formulation of the problems by the operator. In seeking objects, the operator must keep in the operative memory some quantity of objects until he makes a choice. In the problem of the placement of objects in the order of execution, the operator must keep in his memory the sequence which has been found. The problem of the operative memory is particularly complicated under conditions of working with dynamic information models. For this type of activity, it is most important to have such characteristics of the operative memory as volume, storage time, lability, accuracy and noise resistance. The results of a study /14
of a number of authors are discussed. The experiments of G. V. Repkina have shown that the operative memory, formed within the concrete activity, becomes one of the important conditions of its success: for general results of work, the quality, degree of formation and automation of means of forming operator units of memory are of critical importance. One of the effects of training the operative memory, formation of larger units of perception and memory with development by the operator of a statictical structure of objects, is a sharp increase in the results of the work as far as accuracy and speed are concerned. Man has the ability to develop new methods of work and thereby to move from a mode of delayed execution to one of immediate execution.

The problem of investigating the operative memory is one of uncovering the details of this transition. The procedures involved in transferring the operator from working in one mode to working in another are the inner reserves for the optimization of the work.

For both types of activity, the function of the direct instantaneous memory is important. Regardless of the type of activity, an operator who is working with an informational model must create the characteristics of a real situation required by him with the given degree of accuracy. The transfer of information obtained by the operator to real objects is frequently performed by him as a completely conscious, goal-directed activity, which is difficult

to subject to practice and automation. This leads to the need for improving coding systems which can be used to transmit information regarding a situation.

The study of the coding of information in conjunction with the operation /15
of the memory has shown that the optimum conditions for productivity of memory processes consist in the ability to maintain connections between the memory devices and the material to be remembered as well as grouping of the material which will make it possible to reduce the number of its units through enlargement and generalization of "pieces" of information; it has been found to be more effective in solving operative problems requiring considerable stress on the memory to have codes with respect to which it is easier to form large operative units of memory.

Mention is made of the need for evaluating the suitability of coding systems not only from the standpoint of their recognizability but also the processes of the memory as well as the effectiveness and suitability of coding for solving the operators problems themselves.

In conjunction with the work of P. B. Nevel'skiy, mention is made of such criteria of the volume of the memory as the number of elements of material to be remembered and its limitation as far as the work of the operator is concerned. As a criterion, it is suggested that the ratio of the number of groups formed in the material to the number of elements in the group be used.

It is pointed out that the principal influence on the volume of the memory is not the given quantity of information but the decrease in the quantity of information in symbols to be remembered during its analysis in the process of memorization by means of limitation of the alphabet of symbols without changing the symbols themselves as a result of finding general features of superfluity, etc.

P. B. Nevel'skiy found differences in the invariables for short and long-term memory. In the case of long-term memory it is necessary to consider the number of all the items of information to be recalled and the amount of information in one symbol. The optimum conditions for the function of a long-term memory are created when all of the information to be remembered is reduced and the information contained in each symbol is increased.

However, the volume of a short-term memory is limited primarily by the number of symbols, the number of groups or the number of "pieces" of material to be remembered, and if this number is small the information load on the symbol may be increased to any practically feasible value.

The work of V. Ya. Lyaudis describes the characteristics of the process of the formation of elements or the operative units of memory. The principal role in the increase of the volume of memory is played by the separation and development of an optimum means of grouping the material, associated with selection of those features which promote grouping of the elements of a series according to certain rules, which promotes not only completeness of reproduction but also its selectivity.

Bibliography of 21 items.

Leont'yev, A. N. and D. Yu. Panov: "Human Psychology and Technical Progress," *Voprosy Filosofii*, No. 8, pp. 50-65, 1962.

The article is devoted to a discussion of the new features which technical progress has introduced into human labor. While the "executive portion" of labor processes has been simplified, the processes of perception and analysis of information have become increasingly complex and "stressed". The more labor functions are converted into functions of controlling machines, the more completely their psychological perceptive content will increase. The development of complex technical systems of automatic control has shifted the boundary dividing the functions of man and machine, and the problem of the relationship between their functions has moved to a higher level: higher psychic functions of man and similar functions carried out by automatic devices have begun to be subjected to a mutual merger.

The existence of a serious failure in matching the capacities of man and those of modern automatic systems which actually exist is confirmed. As of the present time, there are still no machines which are capable of genuine objective visual perception; the structure of objective perception in man, in addition to other operations, involves as its principal branch operations involving active separation in the object of its sensory content, an adequate goal of the sensor. It is precisely the process of extraction of the most

"informative" content which modern automatic machinery is incapable of performing. Human perception is characterized by the fact that it is able to operate with insufficiency of informative features contained in the object, and is thereby capable of employing the extensive information which is not encoded directly in the features of the object. It is obvious that the schematic diagrams of the processes of perception which are used by man and modern machines will show no agreement. The systems of modern perceptive devices simulate the processes of perception to an inadequate degree. These systems are abstracted from psychological reality, and this consists in the fact that a specific product of human perception is the shape of an object and not the code of its features which is utilized for solving a specific problem. It is a fact that the principle of signality which forms the basis of all codes, although it is simultaneously a principle of reflection, is not its only principle, however. The image as a result, as a subjective product of perception, may be transmitted by a code, but it itself is a reflection which is compared in terms of its richness with the reflected reality itself. This reality which is created by the brain is in the past, present or exists as a perspective, a goal, and becomes the internal ideal of the "operator" for the activity of a man including the activity of perception itself. /18

In order to simulate these processes, it is necessary to understand to a much greater degree the structure of the processes of human perception than we are currently able.

With the considerable practical results of simulation of memory, the method of functioning of the machine memory and therefore its functional capacities are still less similar to the human memory than the perception of a human being to the perception of a machine. The machine memory models only a partial mechanism of memory, i.e., the mechanism of formation of engrams, or tracks which are capable of being reproduced.

Still more complicated is the problem of simulating thought. The possibility of simulating thought nowadays is practically limited only to such mental operations in which an unambiguous system of rules (algorithms) may be found.

Thus, the principal characteristics of human activity are not reproduced by any machines that have been constructed thus far. Moreover, there are no machine analogies for the fact that it is always important for man how he relates to his work. We know that by placing an appropriate goal before an individual we can increase his output considerably. The most exquisite property which all machines have and which man does not have is the possibility of maintaining machines under conditions when they do not work and are not subjected to external influences. It is impossible to keep man "in complete readiness" under similar conditions. It is impossible for a man to do nothing and feel nothing without punishment. He must be active. And this characteristic, completely absent in machines, clearly expresses its deepest significance. /19

Mention is made of the error of viewing man only as a branch of an autonomic complex of machines, a branch which still remains (in some annoying fashion) unreplaced by automatic devices. The changes in human function which have been produced by the march of technical progress cannot be understood by removing man from the sphere of production. The problem of "man and machine" is not only a practical one but also is important from the theoretical standpoint as far as the theoretical relationship between those processes which are carried out by the machine and the human activity are concerned. Even the most automated systems from the human standpoint constitute a method of accomplishing human activity. He gives them an enormous number of functions which are inaccessible to him due to their complexity. But these functions have been developed by man and in this sense they are converted and substantial human functions.

Lomov, B. F.: *Chelovek i Tekhnika. Ocherki Inzhenernoy Psikhologii*, [Man and Technology. Outlines of Engineering Psychology]. Moscow, "Sovetskoye Radio" Press, 1966. Bibliography of 504 items.

The monograph contains a detailed description of the psychological and psychophysiological characteristics of man which determine his interaction with a machine. Considerable material is presented on the studies of Soviet scientists in the field of psychology, psychophysiology of work and engineering

psychology. Considerable space is devoted to a study of the principles of designing indicators and control elements which will ensure efficient activity by the operator.

Nebylitsyn, V. D.: "Study of the Reliability of Function of a Human Operator in Automated Systems," *Voprosy Psikhologii*, No. 6, pp. 9-18, 1961.

The paper is devoted to a discussion of the problem of "reliability of the human operator", inasmuch as the growth of complexity of systems on the whole has led to an increase in the responsibility of the operator, who serves as a branch for analysis and transmission of information. As the complexity of his functions have increased, required for operation of the machine, the human function has not only failed to be simplified but rather has shown a tendency to become more complicated, since at the current level of technical refinement the principal intellectual functions of a human being cannot be duplicated by an electronic mechanism.

The reliability of a human being as a means of retaining required quality under conditions of possible complication of a situation is given as "retainability", the stability of optimum working parameters of an individual. There is a discussion of the relationship of the concepts of reliability and efficiency; while efficiency is understood to be the success of productivity of a system, reliability is one of the conditions which governs the efficiency of a system. It is pointed out that the level of reliability of a subject /21
cannot be determined to a reliable degree under conditions which do not impose increased requirements on one of the characteristics of reliability. Optimum conditions conceal individual differences in reliability, maintaining them with respect to the efficiency of operation. Tests of human reliability require his shift to extremal conditions.

A determination of failure is given; this is the cessation of operation due to development of an organic or functional, reversible or irreversible process in the sensory, motor or cerebral spheres of the subject. In the broad sense of the word, failure is an event which is accompanied by a deterioration of the efficiency of the working process. In this case, the category of failures will include the entire range of erroneous actions by the operator which have as their result incorrect final effects.

It is proposed that the following be used as criteria for a quantitative estimate of reliability: (1) the average work time between two failures (errors); (2) the total number of failures in a given time interval; (3) the percentage of tasks accomplished; (4) the probability of satisfactory error-free operation during a specific time interval.

Three principal groups of factors governing the reliability of a human operator are discussed: (1) the refinement of the apparatus from the engineering-psychological standpoint; (2) training of the operator; (3) individual differences (anatomical-physiological factors, psychophysiological factors and psychological factors).

There is an enumeration of the principal characteristics of reliability of /22 an operator and an indication of those psychophysological qualities on which it may depend.

Long-term tolerance during monotonous work must be associated with strength of the nervous system.

Ability to withstand extreme stress and overstress in emergency situations, ability to think critically and adopt solutions with a lack of time. This characteristic is determined either by the strength of the nerve processes or by balance.

Noise resistance, i.e., the ability to withstand the distracting effect of external influences; the basis of this is the ability of the nervous system to develop strong dominant foci of stimulation.

Spontaneous distraction -- this is also related to the parameter of strength or weakness of the nervous system. The concentration of nerve processes is a function of the strength of the nervous system.

Reactions to unexpected stimuli. The development of an unusual signal causes the appearance of a period of "psychological refractoriness," when the perception of the operator and his intellectual functions become narrow, he concentrates on the source of the unexpected stimulus, and his alertness in respect to information of other kinds is reduced or completely inhibited. For the concept of reliability, it is interesting to study the individual

differences in the length of the "interval of psychological refractoriness", governing the duration of the period of deviation from basic activity during which there is a sharp increase in the probability of errors. In this case, the balance of nerve processes plays a role.

Changeability. Transition from one function to performance of another /23
requires time which is usually spent in "settling in" to the new activity. During the process of the transitional activity, errors in changing over develop in some individuals. Changeability is associated with mobility of nerve processes in macrointervals of time.

Resistance to the effect of environmental factors -- stability of psychic functions to their influence has to do with the strength of the nerve processes.

We would like to point out in conclusion that for monitoring the reliability it is desirable to use electroencephalograms. Thus, development of carotid inhibition is associated with the development of slow oscillations in the EEG; unpleasant influences of the environment create readily visible changes.

Bibliography of 24 items.

Section 2 - Indices and Methods of Studying Working Ability /24

Several methods of evaluating working ability of cosmonauts during flight have been discussed in [29, 40, 41, 42, 45, 48, 47]. In these papers, psychological and psychophysiological tests and recordings of physiological functions are proposed, and comparison of the results of completing these tests on the ground and in flight is proposed as a source of indications (see pages 27-23). The following are among the methods used under terrestrial conditions for simulating individual physiological and psychological flight factors: recording of physiological characteristics (EKG, SKG, EMG, EEG), by chemical indices, qualities of activity (latent period of the motor reaction, time and error for carrying out psychological tests). Anechoic chamber tests have proven to be most specific for studies of the working ability of cosmonauts as a method of studying the dynamics of working ability [13-53]. Similarly, the method of varying modes of daily activity in the course of multi-day tests [65] as well as during weightlessness and overloads [1, page 2 and 2, p. 33]. The specific reactions indicate the dynamics of the latent period of motor reactions as a function of schedules for daily activity (table on page 35), differences in characteristics of the EEG during fatigue and drowsiness [16, 17, p. 36, 37], complicated working movements with different characteristics [31, 41, 42, 29, 30], and also in the state of the visual analyzer [77, p. 32].

In addition to the complex of methods and indicators used for the characteristic of working ability of a cosmonaut, the following methods and indicators used in psychology and physiology of the work of an operator are also valuable. First of all, there is the combination of physiological /25
indices of stress with indicators of the quality of activity under complicated conditions [46, pages 42-46, 68, pages 20-23]. The method of complication of the working conditions is of greatest importance. For complication, in addition to the physical effects (hypokinesia, hypocapnia, hypercapnia, vestibular stimuli), psychological effects are used: insufficiency of the informational model [33], development of stress situations [28], imposition of an additional task [26], increasing the order of astatism of the control system [64].

The physiological indicators of the state in the process of working are discussed in [46, 7]. The EEG indices [80, 66, 69] are acquiring ever-increasing significance in the evaluation of the condition and working ability under complicated conditions.

To evaluate the state of working ability and the effectiveness of the operator, in addition to the ordinary time and accuracy characteristics, certain formalized indicators [18, 70] are used, but so far formalization of the evaluation of working ability and reliability still cannot serve as a principal method of analysis (thus, it is necessary to introduce into the formula such a quality as "creative activity of man" which have not yet been subjected to qualitative evaluation).

Also characteristic are data which indicate the impossibility of an unambiguous evaluation in terms of physiological indices of the state of the working ability of the operator [63], as well as the absence of specificity of EKG indices, respiratory movements and biochemical reactions for evaluating the working ability of the operator and pilot [27, 50]. Highly complicated relationships have been discovered between the changes in the EEG and the productive behavior under stress [82, 83]. /26

Abstracts of papers which describe the indices and the methods of studying working ability are presented on pages 26-60.

Yeremin, A. V., Kas'yan, I. I., Kolosov, I. A., Kopanev, V. I. and V. I. Lebedev: "The Problem of Working Ability of Man Under Conditions of Reduced Weight," in the book: *Mediko-Biologicheskiye Issledovaniya v Nevesomosti*, [Medico-Biological Studies in Weightlessness]. Moscow, "Meditsina" Press, 1968, pages 405-409.

This article deals with general problems of working ability of man during space flight. On the basis of the subjective reports of cosmonauts, the individual results of the activities and the psychological tests they performed, conclusions are drawn concerning the retention of the high level of working ability during space flights lasting up to five days, with good preliminary preparation, fixation at the working sites and simple working operations.

Bibliography of 12 items.

Ivanov, Ye. A., Popov, V. A. and L. S. Khachatur'yants: "Study of Visual Working Ability in Space Flight," paper delivered at the 18th Congress of the International Astronautical Federation, Belgrade, 25-30 September 1967. /27

The paper discusses the changes in the visual working ability under the influence of space flight factors and the results of a study carried out during space flight are presented. In evaluating the change in the working ability for dashed-line worlds, an increase in the thresholds of perception from 20 to 42% was obtained.

A description of the method of analysis of dynamics of the resolving power of the visual analyzer in flight, based on objective evaluation of subjective reports of cosmonauts, is given. Conclusions are drawn regarding the increased visual acuity during perception of objects having linear extent from space.

Ivanov, Ye., Popov, V. and L. Khachatur'yants: "Orientation and Activity in Unsupported Space," *Aviatsiya i Kosmonavtika*, No. 7, p. 20-24, 1966.

On the basis of motion pictures of the activity of cosmonaut A. Leonov during his spacewalk, data were obtained concerning the parameters of movement of the cosmonaut. These data were compared with data from aircraft training.

An analysis of the data showed that the characteristics of movement during departure from and return to a craft in space show little difference from the characteristics during training. /28

Mention is made of the necessity of ground training for preparation of undesirable movement in space. The habits which were developed were retained during the spacewalk, and the decrease in the quality of performance of individual operations did not exceed 30 to 40%.

Ivanov, Ye. A., Popov, V. A. and L. S. Khachatur'yants: "Working Ability of Cosmonauts in Weightlessness and Unsupported Space," in the book: *Mediko-Biologicheskiye Issledovaniya v Nevesomosti*, [Medico-Biological Studies in Weightlessness]. Moscow, "Meditsina" Press, 1968, pp. 410-439. /29

Parameters	Units	Training Data		Data on Space Walk		
		Departure	Return	1st Depar.	2nd Depar.	Return
Time for Completion	Sec	3.95	9.4	4.08	4.17	10.4
Average rate of movement	cm/sec	127	53	104	73	48
Maximum speed	cm/sec	153	127	160	77.8	150
Maximum rate of acceleration	cm/sec	235	79	325	157	132
Maximum braking acceleration	cm/sec	300	98	700	125	36
Maximum increase in acceler.	kg	23.2	7.8	12.2	15.5	13
Maximum increase during braking	kg	29.7	9.0	69	12.4	3.56

For the purpose of studying the working ability in space, the following methods were employed:

- psychophysiological analysis of work operations including the biomechanics of movement;
- method of simulating individual elements of cosmonaut activity (his operative memory and performance of tracking problems);
- use of dashed-line worlds and special color tables for comparing the brightness of colors with the brightness of the field of a black-white wedge.

- Comparative analysis of the career histories on the ground during training and during flight show that the characteristics of movement of the cosmonauts on Earth and in open space differed insignificantly, although the rate of movement slowed down by 20 to 30%. Losses in spatial orientation were not observed, because the conditions of orientation were determined by the coordinate axes of the craft.

Evaluation of the operative memory was performed by showing the cosmonauts a series of cards with outlines on them, which the cosmonauts were obliged to

trace. Under spaceflight conditions, there was a decrease in the operative memory which was maximum during the first 10 hours of the flight.

An evaluation of the performance of the task of tracing showed a deterioration of control by signals having a frequency above 0.5 Hz against a general background of retention of the quality of tracing.

The evaluation of the operative visual working ability showed a decrease by 20 to 40%. /30

Bibliography of 29 items.

Kakurin, L. I. and Yu. N. Tokarev: "The Problem of Studying the Working Ability of Cosmonauts in Experiments, in Connection with the Problems of Space Flight," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology]. Moscow, "Nauka" Press, 1964, Vol. II, pp. 226-234. Bibliography of 9 items.

The problems of physiology involved in the work of cosmonauts are discussed, namely: study of the possibility of carrying out work assignments at all stages of the flight. Mention is made of the general conditions of activity in the spacecraft: hypokinesia, change in diurnal rhythm, sensory deprivation, increased concentration of attention and constant readiness of the crew for activity in a new situation. Although the work of the cosmonaut is mental, the muscular component of the activity retains its significance, whence the necessity of studying the influence of flight factors on the working ability and the physical state of man.

The article discusses a number of methods which were developed for studying the state and working ability of cosmonauts Nikolayev and Popovich in flight: biotelemetric information, characterizing the state of the basic physiological systems of the organism, television monitoring of behavior, motor activity and posture; radio communication allowing evaluation of the characteristics of speech formation, accuracy of performance of individual work operation; evaluation of the volume and quality of performance of tasks. /31 Data obtained during the flight are compared with background data obtained on the ground during simulation of the work of the cosmonauts in a mockup of the

spacecraft. The subjects were examined for three days, working in the positions and suits worn by the cosmonauts. To evaluate the working ability, the following tests were employed: (1) transmission of a text using the Morse code; (2) psychological tests (naming geometrical figures and oral counting), analysis of reports and entries in the ship's log. As a result of this work, certain tests are recommended for use in flight.

Kosenkov, M. M. and A. P. Kuz'minov: "Some Results and Problems of Observation Under Space Flight Conditions," paper delivered at the 3rd International Symposium on Bioastronautics, San Antonio, Texas, 16-18 November 1964.

The results of the following experiments are described: (1) testing of the spectral sensitivity of the eye under conditions of weightlessness. (2) Investigation of visual acuity of cosmonauts both during injection of the spacecraft into orbit and under conditions of orbital flight. (3) Determination of the possibility of detecting various natural terrestrial formations. (4) Determination of the optimum conditions for illumination in the cabin of the spacecraft.

1. It was found that the spectral sensitivity of the eye during weightlessness remains close to those values which were measured on Earth. /32

2. The measured visual acuity (using Landolt rings) shows that with an acceleration of 1-2 g the visual acuity remains unchanged; at higher accelerations, there is a deterioration of visual acuity and a reduction of the angle of the field of vision. In orbit, the visual acuity rapidly returns to normal and does not differ from that measured on Earth by more than 10%.

3. It was established that the cosmonauts clearly saw settlements, rivers, lakes, mountain ranges, etc., i.e., objects which had an angular dimension of 10-15 minutes.

4. It was found that during orbital flight the brightness in the work areas had to be on the order of 10-15 nits. When the spacecraft entered orbit under the influence of acceleration the brightness in the work surfaces had to be raised to the order of 20-50 nits.

Popov, V. and N. Boyko: "Vision in Space Flight," *Aviatsiya i Kosmonavtika* No. 3, pp. 73-76, 1967.

The article deals with the change in visual acuity and visual working ability of the crew of the "Voskhod-2" spacecraft in comparison with the same indices under terrestrial conditions. The article contains comparative results of studies in the laboratory, in a spacecraft mockup and in flight. Dashed-line worlds were used as a test.

TABLE 1. VISUAL ACUITY

	In the Laboratory	In the Spacecraft Mockup	In Flight
Leonov	1.7	1.4	1.64
Belyayev	1.7	---	1.34

TABLE 2. VISUAL WORKING CAPACITY /33

	In the Laboratory			In the Spacecraft Mockup			In Flight		
	Rel.	Working Time	Visual Acuity	Rel.	Working Time	Visual Acuity	Rel.	Working Time	Visu. Acu.
Leonov	100%	36 sec	0.95	88%	60 sec	1.1	75%	90 sec	1.2
Belyayev	100%	43 sec	1.17	-	-	-	81%	-	1.1

Pointing out the definite changes in the functional capacities of the visual analyzer, the authors suggest that the reason for the decrease in visual working ability in the observation of such fine details as dashed-line worlds is the deterioration of coordination of groups of oculomotor muscles during weightlessness.

The study of the ability to see the color of objects in space flight has made it possible to obtain data on the decrease in the ability to perceive the brightness of colors by 26.1% in Belyayev and by 25% in Leonov (in the case of purple, blue and red) and approximately by 10% for the other colors.

Barer, A. S., Yelifeyev, A. S., Panfilov, V. Ye. and S. A. Rodin: "The Human Operator Under the Conditions of Exposure to Accelerations," *Kosmicheskaya Biologiya i Meditsina*, Vol 2, No. 1, pp. 54-58, 1968.

The authors studied the activity of a human operator under conditions of exposure to accelerations in the cabin of a centrifuge, equipped with visual and audible zero-indicators and three-position relay control devices which could be switched on by moving the thumbs. The subjects were placed in /34
the cabin at an angle of 80° to the acceleration vector. During the action of the accelerations up to 8 g, the control showed no variation from the original; under the influence of 10 to 12 g, there was some deterioration but it was within the limits of permissible deviation; satisfactory quality of control was retained up to 18 g. The recording of information was not disrupted.

In conclusion, the authors mention the considerable reserve capacities of the organism under conditions in which optimum conditions of activity are assured.

Bibliography of 18 items.

Myasnikov, V. I.: "Investigation of the Rate of Responsive Motor Reaction by the Polyeffector Method," in the book: *Problemy Kosmichesoy Biologii*, [Problems of Space Biology]. Moscow, "Nauka" Press, 1964, Vol. III, pp. 235-244.

Eighteen experiments were performed involving a stay in isolation for 10 to 15 days. Various modes of diurnal activity were used in the experiments: conventional, altered (awake at night, asleep in the day) and fractioned (numerous changes in periods of wakefulness and sleep).

Table 1 shows the average values for the latent period of motor activity with the normal mode of diurnal activity (the time is shown in msec).

Similar results were obtained in an experiment with a fractioned /35
schedule.

Time of Investigation	Days of the Experiment				
	4	7	9	10	11
Second day of the experiment	426	426	426	426	426
Subsequent days of the experiment	331	317	306	297	306
The difference in average values exceeds the error in the difference of these values by -- times.	4.08	5.22	5.71	6.19	5.71

With an altered schedule, the results obtained were slightly different. The average values for the latent period of motor reaction (in msec) with the altered mode of diurnal activity are shown in Table 2.

Time of Study	Days of Experiment					
	3	5	7	12	13	14
Second day of experiment	331	331	331	331	331	331
Subsequent days of experiment	271	301	284	376	456	423
Difference in average values exceeds error in the difference of these values by -- times.	4.28	2.14	3.57	2.87	9.23	4.09

An analysis of the results showed that staying in a state of isolation leads to a change in the reaction time, and the nature of the dynamics of the latent period depends on the mode of diurnal activity.

A decrease in the latent period in the normal and fractioned modes is /36 explained by training; this is indicated by the extinction of cutaneous-galvanic reflexes toward the end of the experiment.

An increase in the latent period with an altered schedule is explained by fatigue. The first signs of fatigue showed up in the data from the electro-encephalograms: a decrease in the amplitude of the biopotentials, development of diffuse slow waves, a sluggish nature of the exaltations of the alpha rhythm, a decrease in the reactivity and excitability of the cortex.

Bibliography of 35 items.

Gorbov, F. D. and V. I. Myasnikov: "Trace Reactions in the EEG of Man and Their Significance in the Evaluation of the Functional State of the Organism," in the book: *Problemy Kosmicheskoy Meditsiny*, [Problems of Space Medicine]. Moscow, 1966, pp. 127-129.

A method is proposed for evaluating the functional state of the organism through the characteristics of the electroencephalogram.

The delayed nature of the exaltation of the alpha rhythm (i.e., interrupted by the action only of a subsequent stimulus) against the background of diffuse slow waves and a decrease in the amplitude of the biopotentials of the brain to the original curve of the EEG is a reliable sign of fatigue. On the other hand, brief bursts (up to 10 seconds) of the synchronized and exalted alpha rhythm are characteristic of the sleeping state.

Gorbov, F. D., Myasnikov, V. I. and V. I. Yazdovskiy: "Certain Functional Changes in the Human Organism During Prolonged Isolation," in the book: *Aviatsionnaya i Kosmicheskaya Meditsina, Materialy Konferentsii*, [Aviation and Space Medicine, Materials of a Conference]. Moscow, 1963, pp. 137-140. /37

States of stress and fatigue were evaluated in 18 subjects who were kept in a continuous state of isolation for 10 to 15 days. The evaluation of the functional state was conducted on the basis of data from observations of the behavior and emotional reactions, dynamics of the bioelectrical activity of the cerebral cortex, the results of the determination of the rate of responsive motor reactions as well as on the basis of the actual performance of psychological tests (tests involving noise resistance during work with a black-red numerical table).

The development of emotional stress is observed during the first two days of isolation: this takes the form of a change in the facial expressions and the intonation of the voice; the electroencephalograms shows indefinite alpha rhythm against a background of beta activity; the index of the alpha rhythm decreased by 8 to 40% relative to the original level. There was an increase in the excretion of 17-ketosteroids in the urine. The latent period of motor reaction was characterized by considerable variability, and individual errors

at the beginning and in the middle of the work were observed during investigation of noise resistance.

Beginning with the 6th through 8th days of the experiment, the subjects experienced sensations of fatigue. The EEG showed a decrease in the amplitude of the biopotentials, the development of diffuse slow waves on the original curve of the EEG and a decrease in the reactivity and excitability of the cortex.

The investigation of the motor reactions at this time showed statistically /38
reliable decrease in the rate of reactions by 120 msec on the average. A study of noise resistance showed that the activity level decreased. There were errors both in counting and in the rules for indicating numbers. There was also an increase in the total time for working with the table.

Studies showed that a sharp limitation of general afferentation has a significant influence on the subjects. The use of the method of complex recording of psychological and physiological indices made it possible to establish the qualitative characteristics of these changes and, what is most important, to determine and define the states of stress and fatigue.

Zharov, S. G., Baykov, Ye. A., Kas'yan, I. I., Kuz'minov, A. P., Maksimov, D. G., Onishchenko, V. F. and V. A. Popov: "The State and Working Ability of Man Under Conditions of Prolonged Stay in a Spacecraft Mockup," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology]. Moscow, "Nauka" Press, 1967, Vol. 7, pp. 159-169.

Data are presented on the general condition and working ability of a human being during a 12-day stay in a spacecraft mockup. With the subject in the cabin, continuous monitoring for the purposes of investigation was carried out using television cameras, recordings of physiological functions, and a number of psychological methods. The study of the transmission capacity of the visual analyzer was conducted by means of tables made up from Landolt rings. /39
As a criterion for evaluation, we used the time required to examine the tables, and the number of observed and missed useful signals.

During the experiment, the subject developed signs of general asthenization. The reliability of his function underwent a number of changes: during

the first three days, there was an increase in the amount of time expended in the "orientation of the craft," during the subsequent days the time did not vary from the original, and on the 7th and 11th days there was a decrease in the accuracy of completion of problems. When working with a teletype, there was an increase in the transmission time of a single signal (from 0.7 to 0.8 sec), and the general working ability decreased by 10%. The transmission capacity of the visual analyzer decreased from 1.7 to 1.3-1.5 bits/sec, the loss of valuable information increased by 8-10 signals, and the time of detection of signals increased by 30-60 sec. An analysis of the EEG at the end of the experiment showed a constant exaltation of the alpha rhythm, and a decrease in the bioelectrical activity of the muscles, with a decrease of 26% in the amplitude of the GSR (Galvanic Skin Reflex).

Bibliography of 16 items.

Zharov, S. G., Kuz'minov, A. P., Kas'yan, I. I., Maksimov, D. G., Onishchenko, V. F. and V. A. Popov: "The Problem of Investigating Working Capacity of an Operator Under Conditions of Prolonged Stay in a Spacecraft Mockup," in the book: *Problemy Kosmicheskoy Meditsiny*, [Problems of Space Medicine]. Moscow, 1966, pp. 169-170.

The authors studied the condition of working ability during a three-day and a twelve-day stay in a spacecraft mockup. During the investigation process, recording of physiological functions was carried out. The principal indices of working ability were the accuracy of orientation, the time expended in transmission of information, the transmission capacity of the visual analyzer (on the basis of performance of a corrective test). /40

A three-day stay in the mockup did not change the working ability. In the twelve-day experiment, decreases in the accuracy of orientation of the spacecraft relative to the angular coordinates by 1.5-2 times were observed on the first, fifth, seventh and eleventh days, the time for information transmission increased by 10%, the transmission capacity fell from 1.7 to 1.3-1.5 bits/sec. The EEG showed a reliable exaltation of the alpha rhythm.

Dushkov, B. A., Zolotukhin, A. N., Kosmolinskiy, F. N., Lomov, B. F. and V. D. Nebylitsyn: "Study of the State of Emotional Stress of a Pilot-Operator by Means of Experimental Models of Stress Situations," in the book: *Aviatsionnaya i Kosmicheskaya Meditsina, Trudy III Vsesoyuznoy Konferentsii (g. Kaluga, 10-13 iyunya, 1969 g.)*, [Aviation and Space Medicine, Transactions of the III All-Union Conference (Kaluga, 10-13 June, 1969)]. Moscow, 1969, Vol. I, pp. 204-209.

The article deals with the problem of insufficient development of criteria of reliability for a pilot-operator. Inasmuch as the effectiveness of the activity of a pilot-operator, as the principal element in the control system of an aircraft, is determined to a large extent by emotional stress, the primary problem was the experimental development of a method of analysis of the emotional state and working ability.

An experimental model for neurotizing stress situations is proposed. As /41
a basis for the experimental model, a device is proposed for performance of computation problems according to a set and changing program. The work must be carried out with a lack of time against a background of sensory isolation, relative hypodynamics with a detailed six-hour schedule for work and rest. In the event of errors or exceeding the time limit, the lights went out, bulbs began to flash and an intermittent siren began to operate (90-95 db). The sign "attention" was lit up periodically, which the subjects were required to extinguish by pressing a lever and button.

The experimental data indicate that the degree of emotional stress and working ability differed considerably in individuals with different degrees of preparation. The indices that were recorded in the experiment (frequency and depth of respiration, EKG, sweating on the palms, GSR, EMG (electromyogram) rate and quality of performance of work, operative attention) are quite sensitive to the developing state of stress.

Derevyanko, Ye. A., Kuznetsov, V. G. and V. G. Myl'nikov: "Some Methods of Experimental Study of the Reliability of an Operator," in the book: *Inzhenerenaya Psikhologiya v Priborostroyenii*, [Engineering Psychology in Instrument

Construction]. Moscow, Publishing House of the Ministry of Instrument Building, Automation Methods and Control Systems, 1967, pp. 198-201.

As a criterion for evaluating the reliability of an operator (pilot), the quantitative characteristic of the ability of the operator to perceive and analyze additional information is proposed. The method is based on the /42
assumption of Ye. A. Derevyanko that when fatigue is developing the retention of productivity (quality) at the required level unavoidably leads to a decrease in the maximum capacity of the individual and an increase in the emotional stress. Therefore, by means of measured complication of activity, it is possible to determine quantitatively the additional reserves of the operator under various conditions.

The working stress was calculated by the formula $A = 100 - A_1$, where A is the basic task, A_1 is the additional task. $A_1 = P/P_m \times 100$, where P is the number of reactions during the working time per minute, P_m is the number of reactions during the same period of time before work.

It is not only in the case of fatigue but also in the case of complication of activity that retention of the quality of the latter is achieved by mobilization of the inner reserves of the individual. The optimum compensation becomes possible if the performance of the basic task by the individual does not consume more than 60-70% of his maximum capability.

Bibliography of 5 items.

Kikolov, A. I.: *Umstvenno-Emotsional'noye Napryazheniye za Pul'tom Upravleniya*, [Mental-Emotional Stress at the Control Panel]. Moscow, "Meditsina" Press, 1967.

This book discusses problems associated with the study of stress and physiological changes during emotionally stressful work (176 pages, 12 figures, 6 tables, bibliography of 163 items).

The problem of the physiological bases of mental labor is discussed in conjunction with an increase in the percentage of mental labor in the activity of workers in automated production.

There is an analysis of the data in the literature which indicate a relationship between the various forms of mental stress and the functional state of various organs and systems. /43

A complex method is composed for studying physiological functions of man in various production processes at a control panel. The author used the following methods: 1) time-and-motion study; 2) investigation of the functions of the cardiovascular system (electrocardiogram, arterial pressure and pulse rate); 3) determination of cholesterol, sugar and formed elements in the blood; 4) determination of the excretion of 17-oxycorticosteroids in the urine; 5) studies of electrical excitability and functional mobility (lability) of the visual analyzer; 6) extrapolative studies; 7) studies of higher nervous activity. The material from the physiological studies consists of 2,595 man-hour observations, including 14,646 measurements of work dynamics.

The author mentions the following as the general characteristics of labor processes in the subjects: simultaneous observation of several processes which change with time, rapid switching of attention to various objects and equally rapid accomplishment of acts. The specificity of the conditions is determined by the high degree of responsiveness and stress, as well as the necessity for rapid decisions concerning a number of practical problems under the conditions of a saturated emotional background with complete impossibility of loss of significant time intervals.

The time and motion observations provided a basis for determining the investigated forms of activity as being saturated by work operations and those under stress.

The measurement of the pulse rate and the measurement of the arterial blood pressure give the following results. The pulse rate already showed an increase prior to work, with the maximum speed-up observed when errors were allowed to happen or there were technical breakdowns. The speed-up of the pulse was more pronounced in those workers with less than three years of experience than it was in those with more than three years of experience. The length of time during which the increased pulse rate was maintained was highly significant. In the case of workers using television at a control panel, the /44

maximum arterial pressure increased 30 minutes prior to the beginning of the transmission by an average of 17 mm Hg, reaching a maximum 1.5 hours after the beginning of transmission (by 26 mm on the average). The minimum arterial pressure changed insignificantly. These data are characteristic of workers with less than three years of experience. In the case of workers with more than three years of experience, the maximum pressure increases by about the same amount as for workers with less than three years of experience; as far as the minimum pressure is concerned, it changes to a degree which is much more significant in the workers of this category.

As a result of the measurement of the arterial pressure, the author concluded that the longer the work experience, the more significant the changes in the indices of the cardiovascular system, and that the level of arterial pressure of experienced individuals changes due to the combined influence of acute and prolonged emotional overstress on the organism. Mention is made of data in the literature which indicate that the minimum arterial pressure is an index of the excitability of the sympathetic nervous system or the adrenals. Failure of the arterial pressure to return to the original values by the second day following the work indicates that the nervous system retains the traces of excitation for an extremely long time.

Determination of the sugar level and the counting of formed elements in /45
the blood led the author to conclude that there is a marked increase in the sugar level in the blood during stressful work (up to 140 mg % with an original level of 70-80 mg %), especially with short work experience and the change in the formed elements in the blood.

The investigation of electrostimulatibility on the basis of the rheobase and the lability of the visual analyzer (the method of determining the critical frequency of disappearance of phosphene). The results of the study showed that the nature of the change in the electrostimulatibility of the visual analyzer in workers with less than three years of experience differs from that for workers with more than three years of experience. In the case of the latter, the excitability during the work process also remains elevated until the work is completed, while in the case of the former it increases initially and then

falls below the initial level after three hours of work. The nature of the change in lability is the same for both categories of workers, with the lability initially increasing and starting to fall after three hours of work, but it does not reach the original level by the end of the task. The degree of the change in excitability and lability is dependent on the degree of stress of the work.

Studies in the course of 5-6 hours of work by dispatchers showed that by the end of the task there was a decrease (in 60% of the cases) or an increase (in 40% of the cases) in the physiological functions, and there were changes (decrease) in the accuracy of extrapolation, an increase in the latent periods of the conditioned reflexes, a slowing down of differentiation, difficulty or impossibility of conversion of a negative inhibiting reflex to a positive one, a decrease in lability below the original level, a decrease in the maximum arterial pressure with a simultaneous increase in the minimum, a decrease in the level of sugar and formed elements in the blood. /46

A clearly pronounced relationship was found between the degree of stress of the work (stress state), colored by emotional factors, and the changes in the blood, endocrine activity (excretion of 17-oxycorticosteriods in the urine), certain vegetative functions, as well as changes in the lability and excitability of the visual analyzer and certain indices of higher nervous activity.

We cannot consider as a good indication the fact that almost all of the investigated functions of the organism remain at an elevated level for a long period of time, the period of overstress, when there is not a moderate increase in functions as during the period of development, but a significant one, even toward the end of the task. This state of the organism must be considered dangerous and serious to health, inasmuch as at this time the compensatory-adaptational mechanisms, due to the extremely high overstress and over-excitation, are not in any condition to exercise their protective reaction and even prevent the onset of excessive inhibition.

In conclusion, measures are discussed which promote rationalization of the work of operators and prophylactic measures in the development of neuroses in

cardiovascular diseases in work associated with intensive and prolonged neuro-emotional stress.

Voloshin, V. G.: "Skin-Galvanic Reactions of Pilots to Emergency Situations During Training," *Voyenno-Meditsinskiy Zhurnal*, No. 10, pp. 78-80, 1963.

The paper presents the results of a study of the GSR in pilots with simulation of emergency situations in a trainer. The GSR was recorded according to Ferry (the skin resistance was measured). /47

The relationship between the GSR values (resistance of the skin in kohms) on the degree of significance of the inclination was established. A conclusion was drawn regarding the possibility of using the GSR (according to Ferry) as an objective test for evaluating and comparing the reactions of pilots to various situations.

Il'in, Ye. P.: "Signs of the Optimum Working State of the Motor System in Man," in the book: *Problemy Inzhenernoy Psikhologii*, [Problems of Engineering Psychology]. Leningrad, 1965, No. 2, pp. 17-26.

This article constitutes an attempt to determine the features of the optimum state of the motor system: 1) The maximum manifestation both of the motor function and the function of perception and evaluation of a stimulus. 2) Long duration of work (tolerance) at the maximum level of function. 3) Minimum variability of an index, i.e., stability of the manifestation of the maximum of the function. 4) Adequacy of the evaluation of a stimulus in terms of its quality for the sensory function, and for the motor function, the adequacy of the motor reaction to the stimulus. 5) The stability of the optimum state. 6) At the optimum state, there is both the most rapid transition from the state of rest to the maximum of working ability, as well as the most rapid return to the original level following work. 7) Maximum synchronization in the work of the functional units involved in this system.

In conclusion, it is pointed out that all these features characterize the maximum of a function, the duration of work, stability, resistance, adequacy of reaction, mobility and adaptation during the exposure to various functional /48

units, carrying out this work. By means of training, it is possible to involve the lagging segments in the activity of man, for example, to increase stability if the given feature is of particular significance in the particular type of work.

Bibliography of 15 items.

Suvorova, V. V.: "Changes in the Activity of Slow Rhythms in the EEG as an Index of the State of Discomfort," *Voprosy Psikhologii*, No. 2, pp. 75-82, 1966.

The development of the "stress rhythm" in the EEG (slow oscillations of the biopotential with a frequency of 1-7 per sec) may be used as an objective index of the stress state. The stress is understood to be a state which is characterized by a considerable decrease in the working ability and reliability of a human being under extreme conditions.

The results of the analysis of the EEG showed that the absolute value of the beta-rhythm index does not affect either the depth of the stress state or the degree of productivity in the stress situation. Only the direction of the change is important: an uncomfortable condition is accompanied by an increase in this value, and its decrease corresponds to a productive state in extreme conditions. The quantitative characteristic of the change in activity of the beta-rhythm is unsteady and hardly perceptible (it is possible, therefore, /49 that the EEG does not change during the experiment, but afterward), i.e., the EEG shows more or less pronounced traces of a stress situation.

The author suggests that the direction of the change in the magnitude of the beta-rhythm index is the only objective index of the productive state in the stress situation at the given level of investigation.

In conclusion, it is suggested that it is primarily the specificity of nervous exhaustion, the basis of the stress state, which is responsible for the decrease in excitability.

Bibliography of 23 items.

Nayenko, N. I. and O. V. Ovchinnikova: "Methods of Measuring Indices of the Stress State in the Work of a Human Operator," in the book: *Problemy Inzhenernoy Psikhologii*, [Problems of Engineering Psychology]. Moscow, "Nauka" Press, 1967, pp. 58-75.

It is stated that a great many different ideas concerning the term "stress" can be found in modern literature. This term is defined as the stress phenomena themselves, expressed in the disorganization of behavior including development of neuro-emotional collapse, as well as certain intermediate states which would be more accurately defined as symptoms of psychic stress.

The general changes in behavior in a state of stress are examined: inflexibility of action, change in productivity, inadequacy of reactions, considerable scatter of data obtained in studying sensory and motor functions. Mention is made of the disruption of motorics during stress. A sensitive /50
indicator of muscle stress is the increase in the electrical activity of non-functioning muscles. Among the vegetative indices of stress, the authors mention the frequency of cardiac contractions, the skin-galvanic reaction, arterial blood pressure, etc. Recording of the EEG in emotional states is characterized by an increase in the amplitude of the beta-rhythm with a frequency of 4-6 Hz. In discussing data concerning biochemical changes in the organism, the authors mention the impossibility of a direct comparison of biological changes with psychic stress, as a phenomenon which is incomparably more complex.

In analyzing the detection of symptoms of stress situations in experiments, the authors emphasized the importance of motivation as an independent factor which must be taken into account in analyzing stress.

Bibliography of 17 items.

Nebylitsyn, V. D.: "Reliability of Function of an Operator in a Complex Control System," in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology]. Moscow, Moscow State University Press, 1964, pp. 358-366.

The article discusses the question of the significance of the problem of reliability of a human operator and the fact that human reliability must be

subjected in particular to a qualitative determination. The reliability of a human being is determined as his ability to retain working qualities under conditions of possible complication of the situation. It is pointed out that in order to detect the reliability indices for a human being, he must be placed under extremal conditions. The principal criteria for reliability and three groups of reliability factors are examined.

A number of characteristics of the complex of working qualities of an /51
operator are enumerated, which are related to the stability of their performance of their functions.

As methods of checking reliability in extremal conditions, it is suggested that those indices of psychophysiological functions be employed which will prevent regular changes with changes in the functional state of the subject, for example, electroencephalographic indices.

Bibliography of 23 items.

Gubinskiy, A. K., Lomov, B. F., Mansurov, R. M. and G. V. Sukhodol'skiy: "The Theory of Reliability as Applied to a Human Operator," in the book: *Inzhenernaya Psikhologiya v Priborostroyenii*, [Engineering Psychology in Instrument Building]. Publishing House of the Ministry of Instrument Building, Methods of Automation and Control Systems, pp. 116-123.

The article discusses an approach to the problem of reliability of a human operator, consisting in the fact that the activity of a human being is equated to the action of a component of a control system. It is pointed out that the concept reliability as applied to a human being has undergone practically no formulation; in psychology, physiology and biology, there is considerable ambiguity of this term. Formulation of the basic criteria is proposed.

General reliability of a human being: the property conferred on him by reliability, tolerance, and recoverability, ensuring normal completion of set functions.

Reliability -- the ability of an individual to retain working ability continuously under given working conditions.

Working ability -- the state of an individual in which he is able at a given moment in time to carry out all the requirements that are imposed on him in regard to basic functions, required for achieving a set goal. /52

By failure, we mean complete or partial loss of working ability, including incorrect operations in the absence of necessary actions, while unsuitability is the state of an individual in which at a given moment in time he is unable to handle any of the requirements that are imposed both in regard to basic and secondary parameters characterizing normal performance of set functions.

The concept on which all of the others are based is the concept of working ability or its opposite, the concept of failure. The concrete characteristic of working ability (list of qualities characterizing the state of working ability) is determined by the characteristics of the work to be performed.

Certain quantitative characteristics for reliability of an individual are proposed.

1. Criteria of reliability. The probability of failure Q(t) or error-free operation R(t), frequency of errors f(t), intensity of errors $\lambda(t)$, average frequency of errors $\omega(t)$, average time of error-free operation, working until failure.

2. Criteria of recoverability. Probability of recovery P(t), intensity of recovery $\mu(t)$, average time of recovery t_f.

3. Criteria of general reliability. Coefficient of actual stress; coefficient of readiness K_r, coefficient of downtime K_d.

Selection of a particular criterion still does not solve the problem of the methods of obtaining experimental data. /53

The effectiveness of a human operator is determined as a quantity of actions (or operations) performed by him according to a certain algorithm in a unit time under set conditions Ω in the course of a fixed time interval τ, beginning at moment t. The mathematical expression of this concept has the following form:

$$W_0 = W[A(t), \Omega, \tau, t] \quad (1)$$

where A(t) is an algorithm whose realization begins at the moment W_0 -- ideal effectiveness.

Real effectiveness is determined as the number of operations correctly performed by an individual in the unit time under set conditions. As a measure of the real effectiveness, we used the derivative of the ideal effectiveness for the probability of error-free operation:

$$E_0 = W_0 (t,\tau) \cdot R_0(t, \tau) \quad (2)$$

$$R_0 = R\Omega(t, \tau) = R'\Omega \cdot R''\Omega (\tau/t) \quad (3)$$

where Ω is the collection of parameters of the environment and the state of the individual, $R_\Omega(t, \tau)$ is the probability of error-free operation in the presence of conditions Ω, if t is the beginning of work and τ is its continuation, $R'_\Omega(t, \tau)$ is the probability of the working ability of the individual at a moment t_1, $R''_\Omega(t/\tau)$ is the conditional probability of retention of working ability during the time τ, if he was able to work at moment t.

Sometimes the concept of effectiveness also includes a quality such as the creative activity of an individual. Then the effectiveness will be equal to

$$E_a = W_a \cdot R_a = K_a W_0 R_0 \quad (4)$$ /54

where $K = W_a R_a / W_0 R_0$ is the coefficient which characterizes the creative activity. K changes within the limits

$$0 \leq K_a \leq \frac{E_{lim}}{W_0 R_0} \quad (5)$$

where E_{lim} is the extreme effectiveness which can be attained by the individual

$$E = K_a \cdot W_0 \cdot R'_0 \cdot R''_0 \quad (6)$$

Bibliography of 8 items.

Nersesyan, L. S. and V. N. Pushkin: "The Psychological Structure of the Readiness of an Operator for Extreme Action," *Voprosy Psikhologii*, No. 5, pp. 60-68, 1969.

The level of readiness for action is viewed as a sign of working ability. Mention is made of the need of working out psychological methods of determining the level of readiness for action. Specific characteristics of the activity of an operator do not make it possible to apply direct methods of measuring working ability, inasmuch as it is impossible to measure directly the condition of readiness for extreme action. The authors propose as an index of excitability the use of the "coefficient of working situation" (CWS), the ratio of the average time for completion of an act to the time of completion of the act at a given moment. To calculate the psychological component of alertness, it is suggested that the index of the level of activity be used: the difference between the time of reaction to a signal with and without warning. The studies /55 showed that the given criteria correlate with the success of real function of the subjects (machinists). Three components were found which constitute the structure of readiness for action: 1) the nature of the structure of the action, 2) the general psychophysiological condition, 3) the psychological orientation of the personality. The third component is the most complicated for a objective evaluation: it is the psychological, personal component. Differentiation of this psychological aspect from the integral psychophysiological index was achieved by means of a difference factor (D) between the level of the reactions to the signals with and without warning.

Bibliography of 18 items.

Lomov, B. F. and A. I. Prokhorov: "The Problem of Monitoring the Condition of a Human Operator," in the book: *Voprosy Bioniki*, [Problems of Bionics]. Moscow, "Nauka" Press, 1967, pp. 249-255.

Working ability is determined as that state of an individual in which he corresponds at a given moment in time to all requirements applicable to basic functions that are required for performance of a set task. It is mentioned that physiology and psychology essentially provide data of an

analytical nature, describing only individual, separate moments in the functioning of the human organism and human activity.

The authors expressed the opinion that there is a possibility of using methods of automatic sample recognition for monitoring the state of an individual and the possibility of predicting possible situations as well as the state of the individual. /56

Mention is made of the dependence of the choice of state parameters on the work completed by the individual and the necessity of a special investigation of the basic forms of dependence and especially a detailed analysis of the activity of the operator under conditions under which they are carried out.

There is a discussion of the characteristics of using methods of automatic sample recognition for monitoring the state of an individual.

Mention is made of the theoretical possibility of establishing objective characteristics of state, for example, concentration of attention, and the authors emphasize the complexity of establishing a functional (or even statistical) dependence which would be common to all individuals between the concentration of attention and the selected system of psychophysiological indices. It may be that a completely clear relationship is characteristic only for a certain type of individual or even only for a single individual. In addition, the scale of the degree of concentration of attention may "slide" (relative), i.e., the unit of the scale may not be fixed and consequently it will be necessary to correct it in the course of solution of the problem.

The problem of predicting a condition may require a slightly more complex group of original parameters than is necessary for simple determination. Difficulties in prediction (as well as confirmation) of a physiological and especially a psychic state are made still more complex by the fact that these states do not develop spontaneously. They constitute a reaction to the surrounding medium and are themselves states of interaction of the organism and the medium. Hence, it is necessary to analyze the medium. We must keep in /57 mind the possibility of a change in the functions under the influence of psychic factors (for example, developing danger, etc.).

In conclusion, there is a discussion of the necessity for concretization of problems involving monitoring the state of an operator, and concrete varieties of experimental studies are proposed which are directed at determining the objective criteria of the state, for example, criteria for fatigue, stress, readiness and attention to work on the part of test pilots, etc.

Suvorova, V. V.: "Electroencephalographic Correlates of Individual Characteristics of Human Behavior in a State of Stress," *Voprosy Psikhologii*, No. 2, pp. 35-48, 1965.

The paper presents the results of the use of the EEG method as an objective index of the form and depth of stress. The EEG recording was made until the start of all experiments (background), before and after the experiments. The delta, theta, alpha and beta-rhythms were separated. On the basis of the background recordings of the alpha-rhythm index, subjects were divided into three groups: those with predominance of the inhibiting process, with predominance of the exciting process and the intermediate type. An analysis of the EEG following stress showed that there was a redistribution (on the basis of the alpha-rhythm index) of the subjects: some of the "excitables" became "inhibited", and vice versa. Unexpectedly, we found that groups of subjects that had the same EEG indices showed highly diverse responses to stress as far as behavior, sensations and change in visual sensitivity were concerned. The EEG indices which were used to determine the /58
balance of the nerve processes before and after stress did not reflect any specificity of their state in stress.

A further analysis involved the most reactive rhythms of the EEG with respect to stress: alpha-, theta- and delta-rhythms. Certain differences were established in the changes in the activity of the alpha- and theta-rhythms following stress according to the groups of subjects who were combined on the basis of vital indices. For productive states, i.e., the absence of stress under extreme conditions, there was a characteristic decrease in the index of the theta-rhythm with an increase or stability of its total energy. In the presence of a stress state, there is an increase in the theta-rhythm index with an increase or decrease in its total energy.

As an index of a productive state during stress, we can obviously use not only feelings and behavior but also objective changes in the EEG. Bibliography of 12 items.

Suvorova, V. V. and Z. G. Turovskaya: "Change in the Electrophysiological Activity of the Brain Under the Influence of Instruction for an Experiment," *Voprosy Psikhologii*, No. 2, pp. 59-66, 1968.

The paper discusses the phenomenon of the change in total activity of the biocurrents of the brain under the influence of the instruction for an experiment. In 10 subjects out of 17, there was an increase (up to 300%) in activity following instruction for a "stress" experiment in comparison with "neutral" instruction; five subjects showed a decrease in total activity (up to 21%).

The correlation between the indices of productivity under stress and the /59
decrease or increase in the total activity of the biocurrents under the influence of instruction was not evident. Both the psychological and biological mechanisms and the significance of opposite changes activity remained unclear.

Bibliography of 30 items.

Dlusskaya, I. G., Orlova, T. A., Ponomarenko, V. A. and I. S. Bulakhovskiy: "Biochemical Indices of the Reaction of Pilots to Complex Flight Situations," *Kosmicheskaya Biologiya i Meditsina*, Vol. 2, No. 5, pp. 83-87, 1968.

The problem of the possibility of evaluating the reliability of the actions of an operator in a man-machine system is discussed on the basis of biochemical indicators and the results of an experimental study of biochemical reactions of pilots are presented (on the basis of the sugar content in the blood, the 17-oxycorticosteroids excreted with the urine, etc.) on the extremal influence of an emergency situation.

Conclusions are drawn regarding the nonspecificity of the biochemical indices for evaluation of working ability and reliability.

Bibliography of 12 items.

Kosmolinskiy, F. P.: "Some Problems of Flight Labor Physiology," in the book: *Aviakosmicheskaya Meditsina. Trudy Sektsii Aviatsionnoy i Kosmicheskoy Meditsiny Moskovskogo Fiziologicheskogo Obshchestva* [Aerospace Medicine. Transactions of the Department of Aviation and Space Medicine of the Moscow Physiological Society]. Moscow, 1967, No. 1, pp. 177-183. /60

It is pointed out that the working ability of a pilot at low degrees of influence by external factors remains at a high level due to the compensatory mechanisms of the organism. As the basis for the increase in working ability of an individual together with social and psychological factors (goal-directedness, interest), there are also physiological mechanisms of adaptation and acclimatization to the action of unusual environmental factors. Under the conditions of flight labor, we are constantly encountering adaptation reactions of the organism. The changes in the frequency of the cardiac contractions and respiratory movements during flight, frequently used as indices of neuro-psychic stress, may simultaneously indicate adaptational reactions of the individual to the flight.

Section 3 - Factors Governing Efficiency and Reliability of Action

/61

While the concept reliability, determined as a combination of properties of an individual which ensure normal completion of set functions by him, is used by the majority of investigators in this sense, the concept of efficiency does not have the same distinct meaning; in a number of papers it is used interchangeably with the concept of "reliability" or "working ability", and in some papers it has the more limited meaning of "productivity" and is measured as the quantity of action performed in the unit time. It is obvious that in the the latter case there is no unambiguous relationship between reliability and efficiency, i.e., with a high degree of reliability there may be low efficiency, and within certain limits of time with low reliability there may be high efficiency. In the case of the activity of a cosmonaut in particular, reliability is "problem number one", and efficiency is one of the signs of reliability. Such indices of efficiency in space flight are reflected in [41, 42, 48, 77, pp. 28-33]. It is mentioned in these papers that with a slight decrease in productivity in space the reliability of the individual remains high. In a number of papers [56, 48, 77, 41], mention is made of factors which influence the reliability of actions in space: spatial perception changes in conjunction with weightlessness, there is disruption of coordination concepts regarding space [56, 64], hence an increase in the role of visual and auditory analyzers [64, 78] due to special training and instrument readings. In other papers [40, p. 27], [77, p. 32], mention is made

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made of a slight decrease in visual acuity under the influence of spaceflight factors.

The problem of reliability in space is posed in conjunction with the influence of unfavorable factors, many of which have not been studied in conjunction with the activity of a cosmonaut. However, there are data in the literature concerning the change in the characteristic of activity of an operator under the influence of stress [32, p. 64], [81, p. 65], specific noises closely resembling the useful signal [14, p. 2], [15, p. 66], sensory isolation and weightlessness [53]. Three groups of factors are isolated which govern the reliability of an operator under unfavorable or complicated

conditions of activity: completeness of the apparatus from the engineering-psychological viewpoint, trainability and individual differences [68, p. 21]. The engineering-psychological aspect will be discussed in Section 5.

The individual psychophysiological qualities on which reliability depends are discussed in [68]: in [14 and 15, pp. 2, 3, 66] mention is made of the "noise resistance" as a basic quality of an operator while [53, pp. 68-69] mentions the psychological characteristics of the operator: goal-direction and readiness for action under unusual conditions.

In a majority of papers, preparation of the operator and development in him of habits of perception, anticipation, and motor activity are mentioned as factors which govern reliability. Preparedness also depends on such important factors as self-control, motivation [53], and the ability to anticipate events [10, 87].

Mention is also made in the literature of the considerable adaptive abilities of man, as well as the consciously-willed nature of regulation of his actions by himself [10, 36 , 5, 49, 54, 89, 76, 79, 92, 85, 91, 6, etc.]. Thus, mention is made of the effect of sensory instruction, which leads to development of professional forms of sensitivity, the disappearance of the affect of distortion of the visible world following adaptation to distorting glasses, adequate recognition with insufficient number of characteristics, correct perception under noise conditions [36, pp. 72-77]. /63

Pages 63-87 contain abstracts of the papers in Section 3.

Leonov, A.: "Man in Space: Spatial Perception," *Nauka i Zhizn'*, No. 11, pp. 9-10, 1968.

In this article, the cosmonaut analyzes his personal experience with spatial orientation and perception in space. He mentions that the concept developed on the ground that the spacecraft is "down" was completely retained even during the cosmonaut's space walk. However, there was no complete automation of the coordinate concepts regarding space in which the spacecraft was "down".

Inasmuch as the optical analyzer serves as a source of adequate information under conditions of weightlessness concerning the spatial position, there was a restructuring of the developed system of orientation. The author mentions the development in deep space of an illusion of the voluminousness of the starry universe -- bright stars appear close and less bright ones appear far away.

Mikushin, G. K.: "Perception as a Concrete Thought and Space Flight," in /64
the book: *Materialy XVIII Mezhdunarodnogo Psikhologicheskogo Kongressa, Simpozium 28 "Psikhologicheskiye Problemy Cheloveka v Kosmose"*, [Materials of the 18th International Psychological Congress, Symposium 28 "Psychological Problems of Man in Space"]. Moscow, 1966, pp. 120-121.

General concepts are expressed concerning the possibility of changes in spatial perception with weightlessness. It is suggested that "functional atrophy" of gravity receptors be compensated by increasing the activity of the visual and auditory analyzers.

Zavalova, N. and V. Ponomarenko: "Influence of Stress on the Characteristics of the Activity of an Operator," *Tekhnicheskaya Estetika*, No. 7, pp. 5-7, 1969.

Stress is determined as a specific state of the operator which arises as a result of action of unfavorable environmental factors which constitute a threat to well-being and the life of the operator himself, the persons entrusted to his care or the functioning of an object under his control. The article discusses the ability of an operator to act in stressful conditions in a fashion adequate for the situation and the probable erroneous actions. Some results of the authors' own experimental studies are presented together with data from the literature that discuss characteristics of the behavior of an operator under stress.

It is suggested that retention of effectiveness and working ability by an operator under stressful conditions is ensured by completeness of information regarding the situation.

At the end, there is a list of the typical disruptions of the behavior of /65
an operator in a state of stress.

I. Influence of stress on performance functions: 1) failure due to a) motor stupor with overly strong stimulation; b) impossibility of adopting a solution as a result of disruption of thought; 2) impulsive actions, expressed in haste and thoughtlessness of decisions; 3) delayed action; 4) erroneous actions with correct evaluation of the situation as a result of stress on the operator and defect in the working area; 5) forgetting to carry out single actions.

II. Influence of stress on processes of perception and analysis of information:

1) transition from quantitative reading of instruments to qualitative;

2) failure to perceive a useful signal as a result of increased concentration of attention on other things; 3) deviation of perception of the useful signal.

Suvorova, V. V.: "Some Forms of Development of Stress Under Laboratory Conditions," *Voprosy Psikhologii*, No. 1, pp. 34-44, 1964.

An attempt is made to study the conditions which create stress and change the functional capacities of man in a state of stress. The state of stress is created by posing the individual with an insoluble problem, requiring considerable effort of memory for parallel accomplishment of tasks of similar content.

In the experiments, the authors observed two forms of development of a /66
state of stress -- failure involving stimulation and failure involving inhibition. Conscious control of the task of carrying out an act is temporarily disrupted only in the state of "inhibited" stress. The balance of the processes of excitation and inhibition in stress experiments may not correspond to the balance of stimulation and inhibition in background experiments.

Complication of the problem may lead both to disruption of the balance of the nerve processes (adaptation to stress) and to an increase in the disproportion of the ratios of the nerve processes (stress).

Bibliography of 9 items.

Gorbov, F. D.: "The 'Noise Resistance' of an Operator", in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology]. Moscow, Moscow State University Press, 1964, pp. 340-357.

The concept of "noise resistance" of an operator is introduced to designate the qualities or capacities of an individual to carry out active selection, perform precise differentiation and act in accordance with the set program under conditions of influence of stimuli which are similar in nature to given working elements. The experimental study was preceded by an analysis of the conditions of activity of pilots subjected in flight to suddenly developing and rapidly passing states of ambiguity and perception of the surroundings, undergoing "loss of the thread of thought", rush of heat to the brain. It was found that the direct cause of development of these difficult states in a healthy pilot can be found in the characteristics of activity, in the characteristics of interactions of effects involving control and input of information, required for carrying out these actions. In all /67
these cases, there was an excess of information in the sense that a principal sources of information was duplicated by another. For example, difficult states arose in conjunction with increased demands from the ground, and additional correction commands. The difficult state disappeared completely as soon as the conditions causing it had changed. It was established that the similarity of stimuli which have signal significance requires considerable nervous stress. The informational nature of the "noise" makes it impossible to tune it out; a protective "medium" may become a noise-generating factor.

Description of the method. The subject was required to carry out work with a numerical table, in which numbers were printed in 49 squares: the numbers from 1 to 25 were printed in black and the numbers from 1 to 24 were printed in red. The subject was required to read the black numbers in ascending order and the red numbers in decreasing order, alternating between these activities and mentioning first a black and then a red number. In the course of the entire experiment, the electroencephalograms were recorded (simultaneous monopolar recording from the occipital region and bipolar recording from the "crown-forehead" points). We used the following as

criteria for evaluation: data from general observation, EEG data and the actual results of work (time and errors). As the noise, we used suggestions of similar numbers recorded on a magnetic tape.

The excess information which developed (suggestions) led to a lengthening of the periods between responses and a change in the intonations (increase in the loudness of the responses, emphasis on words, etc.). On the basis of an analysis of 500^{T} experiments with 300 subjects, the authors drew conclusions regarding the different reaction of the subjects to the inclusion of the /68 suggestions. In some cases, the subjects continued to work without error, merely lengthening the working time, while in others the influence led to interruptions, including individuals who showed good tolerance of influence of strong outside stimulation.

The influence of outside stimulation and noise stimulation was not the same. Noise resistance develops as an intrinsic characteristic of the individual, consisting in the ability to carry out active choice and perform precise differentiation under conditions of influence of signals that are similar to the required stimulus. A factor which is of prime significance from the standpoint of influence is the "spreading out" in time of such events as the development of noise and the formation of the appropriate response. At early stages of formation of the response, the suggestion may take the form of a delay, while at a certain stage it evokes the pronounced distracting effect -- "choking effect". The latter arises at the moment when the response is formulated but not realized.

A vulnerable spot as far as noise is concerned is the "anticipation" system, which is a condition of activity.

Bibliography of 15 items.

Kuznetsov, O. N.: "Concept of 'Personality and Environment' in Experimental Space Psychoneurology," *Kosmicheskaya Biologiya i Meditsina*, Vol. 2, No. 3, pp. 62-70, 1968.

For a scientifically based prediction of neuro-psychic resistance to specific environmental factors (a stay in ecologically-closed systems and in weightlessness), special experimental studies are required. Experimental /69

space psychoneurology has as its subject the specific behavioral phenomena under conditions of sensory deprivation and weightlessness and is aimed at a clinical-phenomenological analysis of the unusual psychic states.

General positions are defined which must be used as a basis in setting up experiments, carrying out preparations and selection.

The behavior of the personality under new conditions of existence is determined through an analysis of unusual psychic states from the standpoint of characteristics of orientation as a function of the novelty, unusual nature of the conditions, individual-psychological characteristics and the attitude of the personality.

Individually psychological characteristics of the personality may favor or contradict adaptation of the individual to new conditions of existence.

The preparation of the personality, its experience with adequate orientation and activity under unusual conditions becomes one of the most important aspects of the personality determining adaptability to new environmental conditions.

Analyzing the results of his own investigations and some data from the literature, the author points to the following factors as determining adaptability:

- Knowledge gained in the course of preparation and obtained from life experience governs corresponding behavior.

- The wider and more pertinent the experience forming the basis of the personality of the subject, the more he is able to use this experience and the more easily he can adjust; a high degree of interiorization is necessary for a cosmonaut. /70

Training in an anechoic chamber and the development of independence may increase the general level of interiorization.

Individual characteristics: high degree of coordination of the first and second signal systems, investigatory capacities, self-criticism, self-control, goal-directedness, ability to form adequate concepts regarding unknown conditions, etc.

In conclusion, the author mentions the role of experimental psychoneurology in the development of characteristics of the personality to ensure reliability of the individual in the "cosmonaut-spacecraft" system, and points out the necessity for separating "biological instability" from "pedagogical unpreparedness" for individualization of systems of prophylactic measures.

Bibliography of 28 items.

Gellershteyn, S. G.: "Methods of Experimental Study of the Reaction of Anticipation," in the book: *Problemy Kosmicheskoy Meditsiny*, [Problems of Space Medicine]. Moscow, 1966, pp. 113-114.

A study of the reaction of anticipation may be conducted both in order to understand the psychophysiological nature of the action of a pilot and cosmonaut, as well as for the purpose of constructing systems of training exercises.

The following system of experiments is proposed:

1) experiments in guessing the time of occurrence of impending events, or a rhythmic structure which is broken up into a sequence of development and alternation;

2) experiments with anticipation of the nature of impending changes in the situation; /71

3) experiments with anticipating certain possible changes, stimulating preparedness for selection in the future of an optimum solution from many;

4) experiments with guessing of a hidden logical connection which is broken up into a sequence of phenomena (anticipation, based on deductions);

5) experiments with false anticipation, modelling conflicting situations with differences between the expected and the actual;

6) experiments with a gradual "crystalization" of the situation, predicting in the form of indistinct preliminary signals the possibility of an emergency situation;

7) experiments with the creation of the impression of a certain cycle of actions which precede dealing in future with avoiding traumatizing effects of unusual states, stress, emotional shock, etc.

Feygenberg, I. M.: "Probability Prediction in the Activity of the Brain," *Voprosy Psikhologii*, No. 2, pp. 59-67, 1963.

This article is a treatment of the orientation reaction as a reaction which arises in response to the development of a new situation. Novelty is understood to be lack of anticipation of a change in the situation. Hence, the orientation reaction is viewed as a reaction of the organism to failure of agreement between the existing situation and the situation which was anticipated, predicted, or foreseen by the organism. This reaction to the quantity and importance of information which a specific signal contains for the given organism. /72

In both animals and man, prediction may take place without the individual responding; it may take place in the form of an unconscious form of higher new nerve activity. The source of the prediction is the traces of the time relationships retained by the brain which took place in the past. However, prediction is not only the blind use of past experiences used with extrapolation of characteristics that were observed in a certain group of phenomena to other phenomena.

If the conditioned reflex is the prediction of a certain situation and preparation for it, the orientation reaction is the prediction of an unexpected situation and preparation for action within it.

The processes of probability prediction play an important role in the development of emotional reactions accompanying somatic changes.

Bibliography of 27 items.

Zinchenko, V. P.: "Theoretical Problem of the Psychology of Perception," in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology]. Moscow, Moscow State University Press, 1964, pp. 231-263.

The article discusses the insufficient treatment of the problem of perception from the standpoint of possibility of determining the amount of

information which an operator may perceive per unit time, from the standpoint of predicting the degree of effectiveness of the means of representation which have been developed. The article also discusses the insufficiency of utilization of anatomomorphological and certain physiological principles of /73
operation of analyzers for modelling perception processes.

The following definition of perception is given: it is the action by means of which various forms of conversion of stimuli are given a shape. Arguments are given against identifying the concepts "reception of information" and "perception", against the confusion of perception with elementary sensory processes, on the one hand, and perception with adoption of a solution on the other.

The concept of sensory instruction is presented, or the concept of formability of perceptive actions: the facts of sensory instruction include development of professional forms of sensitivity, disappearance of the effect of distortion of the visible world following adaptation to distorting glasses and distortion of perception as a result of sensory deprivation.

In treating the problem of the subjectivity of perception, the author introduces the concept of the operative unit of perception by which he means us to understand the content separated by the subject in solving his specific perceptive problem. Such units may be (for example) gradations of brightness, outline, signs of objects or their complexes, objects as a whole and complexes of objects.

A description is provided of perceptive operations and actions: detection and isolation of perceptive content, identification with previously isolated perceptive content. As a result of performance of these operations of observation, isolation of informative content and recognition, the shape of the object is composed. When it has been formulated, the existence of a cognitive /74
(and reproductive) action is possible. However, when the image is composed with subsequent presentations of the object, the observer still contributes something from his past experience. Comparison and identification are required for recognition. As a rule, the effectiveness of recognition is determined by a previous process of familiarity with the object. In the

course of familiarization, the observer extracts new aspects, groups them and discards some of them. This shortens the process of identification. As a result of grouping, a combination of several features comes to be identified by the observer as the object as a whole, he can recognize it both "by its face" and by its individual features. Man recognizes an object all at once.

The probability approach to perception is discussed. The author feels that the theory of probability of perception does not involve such essential operations as isolation of informational content and familiarization. The concept of recognition as a subsequent statistical analysis is contradicted by the hypothesis that the mechanism of recognition is based not on the testing of individual features but on their conversion and enlargement. This hypothesis suggests the possibility of conversion of a certain combination of individual features into a complex, into a whole picture. This type of transformation takes place during learning; then the observer changes the operative units of perception; as a result, the method of accomplishing familiarization or recognition effects is altered.

As a second proof against the probability of interpretation of the nature of recognition, there is a possibility of adequate recognition with an insufficient number of statistically reliable features and the possibility of adequate recognition under conditions of noise. /75

It is very important as far as the recognition process is concerned to have a limitation of a great many features which takes place not only due to exclusion of some of them but also due to synthesis of certain features into a whole which is later used instead of certain features which do not form a complex or a system for the observer, but a simple elementary operative unit. One of the possible explanations of the mechanism of formation of such a structure may consist in the fact that the observer proceeds to an operation with another alphabet, changes the operative units of perception. Due to organization of the individual stimuli into a structure, there is an increase in the transmission capacity of the observer and a decrease in the time for recognition and reaction.

The most difficult problem in the study of the perceptive and recognition effects is the content characteristic of various levels of operative units or structural features. Many operative units are formed simultaneously and are mutually replaceable to a certain degree. From this we obtain the complexity of the problem of the criteria for perception.

The formation of new methods of perception and new operative units leads to a loss in the rate of perception, places a strain on the operative memory, creates favorable conditions for prediction and anticipation relative to the effect of operative units at the preceding level.

The article mentions the difficulty of solving a problem involving the use of theoretical-informational concepts and measures in the study of problems of perception. It is pointed out that in addition to the difficulties /76
of taking the alphabet of stimuli or operative units into consideration, with which the observer is dealing in reality, in addition to the difficulties of evaluating the subjective probability of their appearance and evaluation of their significance, a difficulty also arises which is associated with the necessity of taking into account those operations which the observer carries out. In practice, this means that when determining the rate of perception it is not permissible to abstract from the psychological problematics of the investigation of perception.

There is also the question of the fact that the data on the transmission capacity of the peripheral branches of the analyzers cannot be used in analyzing real behavior. This transmission capacity of the "natural" forms of modelling, which by itself does not ensure objective perception, cannot explain selective perception. Data from the literature are presented which indicate several characteristics of selectivity of perception. Three stages are discussed into which selection of information can be divided, as well as recoding of material. In the first stage, the individual sees everything and a great deal is stored in his memory, but in a very short time -- up to 0.5 sec. This is the immediate memory. In the second stage, there is a selection of material for retention. This is the operative memory. There is also a long-term memory, in which only a portion of the material stored in the operative memory is kept.

In conclusion, the authors state that the current state of science of perception and its practical applications is such that the extensive logical simplifications of the problems are only slightly effective. Obviously, they must be replaced by genetic simplifications. It is clear from what has been /77
said that there is a limitation to the probability approach to perception which is currently determined by logical simplification but does not follow from an analysis of the genesis and nature of perception.

It would be very interesting to define and describe the perceptive effects which must be carried out by the operator in modern control systems, in addition to a cataloging of operations of recognition and perception modelled at the present time.

Bibliography of 74 items.

Boyko, Ye. I.: "Reaction Time in Man," in the book: *Istoriya, Teoriya, Sovremennoye Sostoyaniye i Prakticheskoye Znacheniye Khronometricheskikh Issledovaniy,* [The History, Theory, Current Status and Practical Significance of Time-and-Motion Studies]. Moscow, "Meditsina" Press, 1964.

The monograph is devoted to a generalization and systematization of data concerning the reaction time in man. A rich volume of material from studies of reaction time to be found in the literature is discussed and analyzed. Neurophysiological mechanisms of goal-directed reactions in man are set forth. The dependence of the reaction time on the features of the stimulus and on the different nature of the influence on the organism as well as individual characteristics and state of the organism is discussed.

The appendix contains a composite table of neutrochronometric data obtained by various authors under various experimental conditions.

The literature contains 395 items.

Kosilov, S. A. and B. A. Dushkov: "Physiological Basis of Accommodation /78
of Man to Specific Conditions of Activity," in the book: *Ocherki Psikhofiziologii Truda Kosmonavtov,* [Outlines of the Psychophysiology of the Work of Cosmonauts]. Moscow, "Meditsina" Press, 1967, pp. 14-32.

The article discusses the organization of the activity of the cosmonaut for maintenance of a high level of working ability.

As a method of preventing fatigue, optimization of the work schedule is suggested: planning of work activity, comparison of the working activity with concepts of correct manipulation. The comparison process involves improvement and refinement of the "total picture of work activity" which is particularly important for efficiency of operation by the operator under the influence of negative flight factors.

The general positions of physiology of skilled labor and the hygiene of labor and rest are presented.

Bibliography of 38 items.

Kuz'minov, A. P., Onishchenko, V. F. and M. M. Sil'vestrov: "The Retention of Skills in Transmission of Information Under Conditions of Prolonged Isolation," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology]. Moscow, "Nauka" Press, 1964, Vol. III, pp. 245-249.

The article describes the influence of prolonged isolation on the working ability and the retention of habits of information transmission. Data from five experiments are described. Use is made of the method of transmitting a text with a volume of 300 printed characters by means of a teletype. To /79
evaluate the working ability, the time required for transmission of the characters was used, as well as number of errors, respiration rate and pulse, change in electrical activity of the flexor carpi ulnaris of the right forearm, and the change in the skin-galvanic reaction during work.

The authors found a decrease in the quality of activity during the first day in isolation, with subsequent recovery during the second and third days, but the number of errors in isolation was higher on the average than under normal conditions.

Chekhirda, I. F.: "The Coordinate Structure and Phase of Conversion of Motor Habits Under the Conditions of Influence of Weightlessness and Positive Overloads," in the book:*Kosmicheskaya Biologiya i Meditsina*, Vol. 1, No. 4, pp. 87-92, 1967.

The qualitative characteristics of the formulation of movements were studied aboard an aircraft under conditions of intermittent action of overloads and weightlessness. The restructuring of the following movements was studied: slow and jerk-terminated flexion and extension of the loaded and unloaded hand. Photocyclography was used as the method. Under the influence of overloads, there is a sharp increase in the small and large errors in the trajectory. Similar phenomena have been observed in weightlessness. These phenomena smooth out with adaptation.

In weightlessness, there is a decrease in the total values of the force vectors applied to the centers of gravity of the limbs, up to 30 to 40% for the longitudinal components and up to 80 to 85% for the vertical. This leads to a decrease of up to 50% of the muscle force. With prolonged overloads /80
(two units) there is an increase in the number of corrections and a complication of the coordination structure of the movements. The paper deals with phases of restructuring of motor habits during brief weightlessness. Phase 1 involves an increase in the time of the movements, an increase in the number of corrections; as the movements are restructured, there is an increase in the role of vertical components of the effort. Phase 2 is marked by the approach of the number and magnitude of the corrections to the original data as the individual becomes accustomed to the situation. In Phase 3, there is a characteristic simplification of the coordination structure of the movements in comparison with ordinary conditions. There is complete transmission of the leading role to the transition of movements from the vertical to the longitudinal components.

A study of the movements is recommended as a test of training.

Bibliography of 6 items.

Plakhtienko, V. A. and V. V. Sofronov: "The Formation of Psychomotor Habits in Operator Activity," *Voprosy Psikhologii*, No. 3, pp. 81-92, 1969.

The paper presents the results and an analysis of the results of an experimental study of the control using a handle and two pedals. The analysis was performed by means of the factor method.

Three stages in the formation of a habit are defined:

1) Formation of psychomotor habit takes place due to reduction of erroneous actions. The principal role in the first stage is played by the sensory-intellectual factor and the factor of the mobility of the nerve processes. During formation of the habit, there is an increase in the depth of perceptive anticipation. This is the stage of senso-motor experience. /81

2) The second stage is characterized both by a decrease in erroneous acts and a decrease in time. There is an increase in the role of proprioceptive factors. This is a stage of motor experience.

3) The third stage is the stage of stabilization, the stage of reliability of the operator functions. This is the stage of the formed habit.

There is a bibliography of 28 items.

Rokotova, N. A.: "Psychophysiological Characteristics of the Solution of Motor Problems by Man," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology], Moscow, "Nauka" Press, 1967, Vol. 7, pp. 27-61.

The author expresses the opinion that only a theoretical study of the higher nervous activity in man can provide a theoretical solution to the question of how an individual is capable of control and the prediction of the means of behavior of an individual with new, still untested systems. In this connection, the author presents the results of studies and the associated hypotheses which touch on the methods of organization of executive activity of man.

The grouping of motor acts for investigation and completion of given sequences was studied. Grouping is the central mechanism of the executive programs and the group of acts is the element of the executive program.

The article deals with the problem of the chronological organization of a sequence of actions in man. With a single repetition of a series of learned movements, the time required for performance both of the entire sequence and the groups of movements composing it as well as individual motor acts varies within insignificant limits. /82

The opinion is expressed that the temporal organization of the sequence of acts in man is associated with the presence of an internal rhythmic process which gives a regular rhythm to the work.

Bibliography of 34 items.

Ushakova, T. N.: "The Problem of the Mechanisms of Attention," *Voprosy Psikhologii*, No. 2, pp. 38-49, 1968.

The article deals with the problem of the limitation of the explanation of the mechanisms of attention of negative-induction relationships. In the opinion of the author, this interpretation is admissible for unconscious attention.

The opinion is expressed that the distribution of attention is accomplished under the condition of an increased excitability in the analyzer of certain nervous areas which work in a single structure. The energetic charge which originates in the reticular formation distributes itself in areas of the analyzer which are connected to the structure. We speak of limitation of activating rising effects, adequate conditions for motivation. Mention is made of the influence on the second signal system, which makes it possible to establish selectively a higher level of stimulatability of individual operating areas of the analyzer through conferring particular significance on the stimulus. /83

Bibliography of 22 items.

Chuprikova, N. I.: "The Reasons for the Increase in Latent Periods of Reactions with an Increase in the Number of Alternative Signals," *Voprosy Psikhologii*, No. 1, pp. 60-74, 1969.

The article discusses and evaluates the fact of a shortening of the increase in the latent periods of reactions with an increase in the number of alternatives up to 5 to 10. Within the limits of 5 to 10 signals, the increase in the latent periods of the reactions with an increase in the number of signals may be explained by the presence of a certain number of dependent nervous structures which are capable of being simultaneously in a state of increased excitability.

An approach is proposed according to which the causes on which the rate of reaction depends consists not in processes of selection which take place following transmission of trigger signals, but in the nature and degree of "expectation", "readiness" or "condition" for detecting a certain signal and reacting in it with a certain movement.

The validity of the thesis of the existence of logarithmic relationships between the reaction time and the number of alternatives is denied.

Bibliography of 42 items.

Ol'shannikova, A. Ye.: "Development of the Law of Forces in Conditions Comparable and Incomparable to the Working Conditions of the Operator," *Voprosy Psikhologii*, No. 5, pp. 31-44, 1962. /84

The paper deals with the problem of the relationship between the effectiveness of the reactions and the intensity of the stimuli. It is pointed out that the factors which distort the direct relationship of the effect on the intensity of the stimulus are as follows: 1) strong non-conditioned support of weaker signals; 2) oriented reflex to a novelty; 3) use of differentiated inhibiting stimuli.

The paper contains results of experimental studies of the relationship of the effectiveness of the reaction on the intensity of the signals under conditions which are comparable to those of the operator's work.

As a result of the experiments, the author concluded that there is no dependence of the reaction to time on the intensity of the stimulus, under those conditions when error-free operation by the operator is required. Responsibility of the operator is viewed as a factor which limits the dependence of the reaction time on the force of the stimulus. The sensory qualities of the stimulus differ at the second plane before determinant psychic nature, depending on the conditions of activity.

Bibliography of 19 items.

Vekker, L. M. and B. F. Lomov: "The Problem of the Structure of Working Activity," in the book: *Voprosy Psikhologii. Materialy Vtoroy Zakavkazskoy* /85

Konferentsii Psikhologov, [Problems of Psychology. Materials of the Second Transcaucasian Conference of Psychologists]. Yerevan, 1960, pp. 324-327.

The paper presents the characteristics of the basic outlines of labor activity. Two groups of components of labor activity are considered: psychic and purely motor.

The following forms of movement are defined: 1) executive, 2) gnostic and 3) adaptive. There are levels of regulation of labor activity which are governed by different forms of reflection: labor activity, regulated by primary forms (sensations and perceptions); regulated secondary samples (concepts) and regulated speech and thought processes.

The paper contains the characteristics of the principal work activities: goal-direction, adequacy of the current structure of the activity to the current status of the object, based on sensory regulation; the function of the equipment; polyeffectiveness; a certain relationship of the fixed automated components which continuously reorganize in the course of arbitrary realized regulation of labor activity.

The psychic components act as regulators of activity. Specificity of psychic regulation consists in the fact that the subjective structure of the action follows from the continuous nature of the regulating effect of the pictures.

The process of formation of working habits includes a change in the nature of regulation of the acts as a result of which there are such aspects of habit as anticipation, possibility of arbitrary regulation of rate and rhythm of movement, etc. /86

Gurovskiy, N. N., Denisov, V. G., Kuz'minov, A. P. and M. M. Sil'vestrov: "Trainers to Prepare Cosmonauts for Professional Activity Involving Control of the Spacecraft and Its Systems," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology]. Moscow, "Nauka" Press, 1965, Vol. IV, pp. 3-10.

The article discusses the primary significance of preparation in ground trainers for the cosmonaut, such training being divided into two groups: trainers and means of physical preparation and trainers for development of professional habits.

Depending on the scope of the modelled problems, the stages of flight and the degree of immitation, the trainers can be divided into universal, complex, specialized and functional.

The idea of the desirability of developing individual habits on simple functional trainers is proposed, such trainers are very expensive and have considerable capacity. The final development of the habit must be performed on specialized and complex trainers which more completely simulate the actual conditions of the activity of an operator in space flight.

The authors point out that it is necessary to have on-board training for long flights.

Bibliography of 1 item.

Nazarov, A. I.: "Study of the Sensomotor Reactions and Motor Habits," in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology]. Moscow, Moscow State University Press, 1964, pp. 326-329.

The article discusses the principal factors which influence the rate and accuracy of sensomotor reactions as well as the mechanisms of regulation of /87
motor habits. As the motor task, the article discusses the problem of matching a tracking point controlled by the operator with a stationary point.

The article discusses the mechanisms for regulation of movement and the author states that cessation of afferent signals to the regulator of the effects takes place under the contol of a special functional system. The principal problems which are solved by these systems are as follows: 1) formation of afferent syntheses and 2) anticipation of controlling .
The afferent synthesis is a previous and necessary condition for the accomplishment of any coordinated movement. It is primarily the results of afferent synthesis which determine what action must be formulated on the effector side in the presence of a given combination of afferent stimuli.

Once the effector system has been triggered, it must be constantly monitored. This correction is accomplished by comparison of given and actual values of motion parameters; the comparison function is carried out by a special afferent apparatus which P. K. Anokhin has called the "acceptor of movement".

The final establishment and automation of the motor habit is associated with formation of a dynamic stereotype, so that the majority of the afferent synthesis becomes superfluous and the entire process associated with the accomplishment of the movement is merely triggered by certain afferent signals. One of the most important results of the formation of the dynamic stereotype is the possibility of anticipation of commands.

Bibliography of 13 items.

A basic and specific influence on the process of analysis of information may be exerted by the factor of weightlessness. As a matter of fact, a number of papers have mentioned the change in the analyzer systems during operation, and the transmission of the leading role during development of concepts regarding spatial position to the visual and auditory analyzers [56, 64]. However, we still have no material relative to the influence of this factor on the mechanisms for information analysis and the resultativeness of the solutions of the cosmonaut, inasmuch as the study in flight of this form of activity was not sufficiently detailed from the standpoint of psychology and did not place considerable requirements on the psychic functions. From the experience gained in aviation medicine, however, we are quite well acquainted with the influence of changes in the gravitational field on the development of illusions of spatial position and the development in connection with this of erroneous solutions by the pilot.

At the present time, under the conditions existing in space, those aspects of human activity have been most completely investigated which have nothing to do with the high level of processes of information analysis and adoption of decisions by the cosmonaut. The following have been studied: simple tracking, reaction to individual signals, movement in unsupported space relative to the craft, perception of simple features of objects [3, 42, 41, 45, 48, 2, 65, 30]. Under these conditions, the cosmonaut is exposed to requirements for "information search with rapid execution" [38, pp. 12-17], characterized by a small amount of information and its ready evaluation, as well as an influence with respect to a previously formulated algorithm. In this case, we can speak only conditionally about the adoption of solutions by /89
the individual, inasmuch as the solution (practically speaking) lies in the signal itself. The effectiveness of the processing of information and adoption of solutions under similar conditions can be evaluated on the basis of the latent period of the reaction, the number of erroneous reactions as well as the method of computing the "transmission capacity" of the individual.

It has been established that under the influence of spaceflight factors the latent period may be doubled in one operator and remain constant in

another [3], i.e., it depends more on the subjective rather than the objective factor. It has been found that in isolation with an altered schedule of daily activity there is a decrease in the rate of reaction [17], and that the transmission capacity of the operator decreases under the influence of isolation [30].

To increase the effectiveness of the processes of evaluating information and adopting solutions, it is suggested for the purpose of compensation of the negative effect of space flight factors that preliminary planning of the work operations and "formation of integrated type of work activity" be carried out [49], i.e., comparison and learning of the algorithm for adopting a solution would actually be undertaken. In [12] it is suggested that the process of adopting a solution be simplified for the cosmonaut by supplying him with ready information regarding solutions.

However, these simple cases do not constitute the essence of the processes of analysis of information and adoption of solutions by the individual. As a rule, the operator (i.e., the cosmonaut), conducts "an information search with displaced execution" [38], for which the process of information analysis is complicated and involves equipment, organization of signals, determination and formulation of problems, and the adoption of solutions frequently assumes choice of alternatives. Adequate analyses of information /90 and adoption of solutions in a complex and unexpectedly complicated situation are performed by an individual on the basis of specific human mechanisms of recognition, formation of the type of object, evaluation of the situation [36, 92], formation of systems for anticipation, systems of anticipation, probability of prediction [75, 10, 77].

The complexity of the course of such processes is expressed in the delay in carrying out the required actions [9, 33], in the distinctive phenomenon of the "locking effect" [15], in all manner of errors [44, 61, 74].

In conjunction with the fact that the function of information analysis is one of the basic functions of the operator in any system, many attempts have been undertaken to provide a quantitative expression for this function; to determine the "transmission capacity", methods from information theory have

been employed [8, 51, 52, 57, 58]. However, attempts at formal utilization (for the purpose of evaluating a complex psychic process) of the theory of information have not led to the expected results. In the literature, human--specific mechanisms for information analysis have been discussed which do not allow (or considerably complicate) the use of theoretical-information measures for evaluating these processes [36, 57]. One of the principal obstacles is the instability of the alphabet of signals used by man, and the dynamics of the operative units of perception and memory [36, 38, 92]. It is obvious that it is precisely this that the diversity in the quantitative evaluation of the "transmission capacity" is related (from 0.7 to 1,200 binary units per second) [88].

Considerable attention has been devoted in the literature to the psychological mechanisms for information analysis [11, 58, 52, 47, 94, 88, 73]. It has been found that external determinants do not determine directly /91 the characteristics for the course of processes of information analysis and adoption of solutions; their effect is refracted through the cognitive design and the regulation by the individual of his activity on the basis of the intake of information. Several articles [58, 52, 47] mention the arbitrary nature of the regulation by the individual of the rate of information input, and [9, 32, 5, 79] discuss the dependence of this operation on the conditions of activity. In [11, 12, 73, 88] the conditions under which a high degree of efficiency of functioning of information analysis and adoption of solutions is attained.

Abstracts of papers in which processes of input and analysis of information and the adoption of solutions are discussed are shown on pages 91-115, and are also found in other sections.

Belyayev, P. I., Leonov, A. A., Popov, V. A., Khachatur'yants, L. S. and V. K. Filosofov: "Certain Dynamic Characteristics of the Operator in Tracking Under Conditions of Space Flight Aboard the 'Voskhod-2' Spacecraft", *Kosmicheskiye Issledovaniya*, Vol. IV, No. 1, pp. 137-143, 1966.

The article discusses the influence of space flight factors on the quality of performance of activity involving tracking. To indicate the input signals, curves were used that were plotted on the paper of a chart recorder.

The output signals were recorded on the same strip. Measurements of the quality of tracking and reaction time were performed under laboratory conditions, in a spacecraft mockup and in space. The rate of travel of the paper was fixed at 5 mm/sec, and reactions to 50 sinusoidal signals and 22 square-wave pulses were recorded each time.

An analysis of the mean-square errors for various sinusoidal signals /92
showed a decrease in the quality of operation when working on the basis of signals at a frequency above 0.5 Hz in flight in comparison with ground conditions. An analysis of the reaction time to a stepwise input signal showed an increase in the latent period of motor reaction for Belyayev from 0.175 to 0.185 seconds on the ground to 0.300-0.320 seconds in flight, while for Leonov there were no significant changes in the latent period of the reaction and remained within 0.180-0.185 seconds.

The principal conclusion from this work is the fact that dynamic characteristics of man do not undergo significant changes under the influence of a twenty-four hour space flight.

Bibliography of 12 items.

Lomov, B. F.: "Accuracy of Work of an Operator and the Characteristics of Errors," in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology]. Moscow, Moscow State University Press, 1964, pp. 368-380.

The article deals with the errors by an operator which are permissible in evaluating the state of a controlled object. The article points out that inasmuch as the operator is frequently the least accurate component in control systems, the reduction of his errors may be more effective for all the systems concerned than a reduction of errors in the "machine branches". For example, it is undesirable to convert a device from accurate to "super-accurate" if the scale and dial are made so that the operator can make gross errors in reading them.

Indices of the accuracy of function of the operator are not constant values like the rate of perception of signals. They change as a function of /93
the signal characteristics, the degree of complexity of the problem, the

working condition and other factors. Thus, with an input rate of 75 signals per minute, 10% of the reactions will be erroneous, at a rate of 95 signals per minute there will be 55% error and at the rate of 120 signals per minute there will be 87% error. However, too slow a rate of operation also reduces accuracy.

In order to understand how accurately an individual can operate and to predict the errors he might possibly make, it is necessary to study the principal characteristics of the process of subjective reflection of working conditions, the object and working equipment.

Bibliography of 6 items.

Glezer, V. D., Kislyakov, V. A., Kozhevnikov, V. A., Chernikovskiy, V.N. and L. A. Chistovich: "Some Problems of Activity of Sensory Systems in Connection with Problems of Space Physiology," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology], Moscow, "Nauka" Press, 1967, Vol. 7, pp. 11-27.

The article deals with problems associated with the obtaining and analysis of information and recognition of sensory samples. Experimental materials are presented on orientation in space, recognition of visual samples and speech sounds. These problems are selected in terms of their application for control of spacecraft.

Operations involving information processing that are carried out by a human being belong entirely to the area of mental activity. It is suggested that mental operations are accomplished by some kind of signals, symbols, categories, and that these symbols form certain ordered multiples (dictionary of thought) and that there are certain rules for analysis and synthesis of groups (sequences) of symbols. The transmission capacity of a system will increase as the translation from the language of the external signals to the language of thought and from the language of thought to the language of activity becomes more simple. /94

A hypothesis was formulated that the optimum method of presenting "input" data to the operator is a combination of oral and visual reports. However,

the optimum control signals handled by the operator must be oral commands, possibly in combination with certain simple motor acts.

The problem of recognizing visual samples was studied. A calculation of the transmission capacity in terms of recognition of individual outline pictures of objects gives the value of 35 to 100 binary units for different observers. Determination of the quantity of information which the visual system can convert per unit time under different conditions and with different parameters of the visual stimuli is necessary for a rational design of devices for transmission of visual signals.

In considering the information, two forms of the latter are defined: information regarding existing parameters of available information and information about solutions. In the second case, it is desirable to use sound signals. However, it is very difficult to use sound signals to transmit a large volume of information. In this case, the optimum solution will be the use of speech signals.

Gavrilov, L. V., Nikolayev, V. I. and V. N. Temnov: "The Results of an Investigation of Certain Work Modes of the Operator," in the book: *Sistema "Chelovek i Avtomat"*, [The "Man and Robot" System]. Moscow, "Nauka" Press, 1965, pp. 197-214. /95

The article discusses the increase in the role of the operator with automation of control, inasmuch as when emergency situations arise the individual must "plug himself in" as rapidly as possible into the system and carry out the necessary actions. To ensure a high degree of efficiency of labor by the operator, it is necessary to create the best conditions for human work, i.e., to place special emphasis on mutual compatibility of the man and machine as branches of a single complex control system. An attempt has been made to clarify the basic factors which influence the duration of the time which the operator loses in converting information. As a result of the experiments, the following conclusions were drawn. The time required for acquiring information with an increase in the number K of various types of signals increases in proportion to the log of K and is determined by the equation

$$\tau_{in} = b_H + a, \text{ where } a = 0.24 \text{ and } b = 0.072.$$

The time required for acquisition of information is determined not by the input information but by the information output from the device, i.e., the entropy of the number of sections in the device. As the quantity of information increases above 4.16 binary units, the transmission capacity of the operator drops sharply to 5 bits per second. The dependence of the selection time of the control organs on the individual information on the signal for the section from 1 to 4 bits is approximated by the expression: $\tau = a + bJ$, where a = 0.30 seconds and b = 0.084 seconds/bit. In the case of logical operations, the dependence of the selection of a solution from the amount of information contained in it may be represented in the form $\tau_d = Kb_d^n$ where K = 0.0021 and d = 1.95. /96

As the influx of information grows, the transmission capacity of the subject tends toward 5 bits/second.

Bibliography of 3 items.

Leont'yev, A. N. and Ye. P. Krinchik: "The Use of Information Theory in Concrete-Psychological Study (Modern Studies of the Choice Reaction)," *Voprosy Psikhologii*, No. 5, pp. 25-46, 1961.

The paper deals with views concerning the significance of using information theory in psychology and measures the inadmissibility of substitution of the scientific-psychological analysis of phenomena by the "theoretical-information" phraseology.

The authors see their problem as consisting in the fact that they must evaluate the problem of using information theory in psychology, proceeding not by the method of abstract evaluations, but on the basis of an analysis of concrete psychological studies in which an attempt has been made to use concepts and methods of information theory.

There is a survey of studies that have been devoted to the problem of using information theory in the psychology of perception; the authors present their own experimental data.

In the conclusion, it is pointed out that determination of the information which is utilized in communication theory excludes specifically human

methods of information analysis, and that the use of use of information theory in psychological studies cannot be limited to the utilization of previously prepared formulas. /97

Bibliography of 33 items.

Leont'yev, A. N. and Ye. P. Krinchuk: "Information Processing by Man in a Selection Situation," in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology]. Moscow, Moscow State University Press, 1964, pp. 295-325.

The paper deals with the problem of the quantitative evaluation of the optimum volume of input information for an operator, whose solution requires the use of adequate units for measurement of the volume of perception. It is suggested that the problem be solved in the light of the basic concepts of information theory.

Data are analyzed which allow Hick to formulate the law concerning the constancy of the rate of information input by man, and that dependence of the time of recovery of information from a quantity of information to be recovered: $T = a \log N$, where T is the average reaction time to one symbol and N is the number of alternatives.

A survey of the data in the literature devoted to the study of the reaction time in the situation of instantaneous selection led the authors to conclude that it is possible to have a quantitative estimate and to predict the activity of the operator whose basic function is perception and information analysis. However, on the basis of the studies of a number of authors, factors have been derived which influence the rate of processing of information and disrupt the relationship established earlier. These factors include: the degree of difficulty of differentiation, or the high degree of trainability, compatibility of stimulus and reaction.

The authors saw their problem as consisting in the discovery of the concrete psychological content of the concept of the quantity of information. /98 They present the results of an investigation of the dependence of the reaction time on the volume of individual information, i.e., on the amount of information contained in an individual stimulus. The empirical relationship

obtained in the experiments with individual information turned out to be highly different both in terms of nature and magnitude of effect than in experiments with average information, where this relationship has a clearly pronounced linear nature.

On the basis of their data, the authors concluded that the psychological mechanism of perception and analysis of individual information is based on the perception by the individual of the probability structure of the presented sequence of signals. The probability of the signal is a real variable, which regularly determines the rate of perception in the selection situation. In the course of perception of the signal characterized by different informational content, a special psychological phenomenon develops -- the operation of expectation or anticipation (to use Ukhtomskiy's expression), which leads to a specific distribution of the reaction time between the frequent and rare signals.

Inasmuch as the factor of "value" significance of information acquires particular importance in the analysis of activity of an operator, the authors describe studies in which different value was ascribed to various signals.

The introduction of the significance factor led to a considerable decrease in the reaction time for the significance signal.

In their conclusions, the authors emphasize the necessity of studying the /99
psychological structure of the activity which comes under the heading of "information". Such variables in the average information as the probability of the signal and the number of possible signals show up in man as the following psychological correlates: the degree of unexpectedness of the signal and the degree of complexity of choice.

Perception of the probability of the signal structure is not a passive reflection of the statistical structure of the signals: on the basis of a consideration of the probability structure, the individual optimizes the process of perception of information so that by losing a little in reaction time to frequent signals he gains considerably in terms of his reaction to the rare signals. This is the effect of active anticipation. Consideration by the individual of the degree of dependence of the signal leads to an increase in

the rate of perception of signals and to the intensification of the process of perception of information. Hence, the significance factor regularly limits the behavior of the individual.

Bibliography of 42 items.

Krinchik, Ye. P.: "Dependence of the Choice Reaction Time on the Magnitude of Individual and Average Information," in the book: *Sistema "Chelovek i Avtomat"*, [The "Man and Robot" System]. Moscow, "Nauka" Press, 1965, pp. 147-154.

The article points out that the situation with which the operator must deal is characterized by a rather high degree of indeterminancy due to the random nature of the events that arise in a complex automated system. In this connection, it is assumed that the modern version of the classic experiment involving the study of the reaction of selection acquires the significance of a model of activity of the operator which makes it possible to study the structure of this probability-determined alternative behavior. /100

The experimental behavior was directed toward a determination of the psychological structure of that reality which is revealed to an individual following the understanding of a quantity of information. The concepts of the amount of average information and the amount of individual information are derived. The change in the average information is accomplished by varying the number of equiprobable signals for the number of signals 2, 4, 8, which amounts respectively to 1, 2 and 3 binary units of average information. The change in the individual information was accomplished by varying the probability of occurrence of a given signal with a fixed number of the latter, equal to 2^M. The number of individual pieces of information change from 0.09 to 4 binary units. The magnitude of average information then varied from 0.33 to 1 binary unit.

The investigation showed that two comparable information measures cause different magnitudes of effect: with a decrease by a factor of two and the probability of one of the two signals, the reaction time only increased by 16 to 18 msec on the average, while an increase by a factor of two in the number of alternative signals leads to an increase in the reaction time by

209 m sec on the average. The dependence of the reaction time on the magnitude of the individual information in the range from 0.09 to 4 binary units is similar in nature to the logarithmic, while the dependence on the average information has a clearly pronounced linear nature. Differences have been observed in the effect of average information, varied in two different ways -- /101
with linear dependence of the reaction time on the quantity of average information $T = a + b H$ with the lines characterized by a different slope angle for the line $H_8 = 209$, $H_2 = 89$ and 69 msec/binary unit. These data do not agree with the findings of Heyman concerning the psychological equivalence of various methods of varying the average information. The author feels that we can speak of the duality of the psychological structure of this reality which is revealed to an individual following the understanding of a quantity of information: 1) the degree of expectedness of the signal and 2) the degree of complexity of the choice. The parameter for the degree of complexity of choice has a much more important influence on the behavior of an individual in a select situation involving selection than does the degree of unexpectedness of the signal.

In conclusion, the authors discuss the existence in the situation modelling the transmission process for information of two types of indeterminancy: temporal and alternative. Depending on which informational measure (individual or average) is being used and what method is used to vary the average information, one type or the other of indeterminancy will play the critical role. It is much easier for an individual to handle temporary indeterminancy than alternative. It is obvious that in the case of temporal indeterminancy the individual forms its subjective probability model which enables him to predict the moment of occurrence of a rare signal. The operation of "expectation" which arises on the basis of the concept of the probability structure is the psychological instrument for overcoming the temporal indeterminancy.

Bibliography of 8 items.

Krinchik, Ye. P. and S. L. Rysakova: "The Influence of the Signal /102
Significance Factor on the Process of Information Processing by Man," in the

book: *Sistema "Chelovek i Avtomat"*, [The "Man and Robot" System]. Moscow, "Nauka" Press, 1965, pp. 155-159.

The authors studied the influence of the degree of significance of the signal on the dependence of the reaction time on the quantity of average information. Two of the eight signals were given the significance of emergency signals; the experiment was terminated when the individual did not react to them in time.

The influence of the significance factor appears with a considerable decrease in reaction time to the signal (by 320 msec). The effect was achieved by means of a particular restructuring of perception and reaction to signals. There was a change in the subjective relationship of the individual to the signals, which created in him a condition of increased mobilization with respect to particularly significant signals. Particular interest was associated with the fact that the slope angle of the line characterizing the dependence of the reaction time on the quantity of average information decreased (constant "b" in the equation $T = a + bH$), inasmuch as the decrease in the constant "b" indicates an increase in the rate of processing of information by the individual. The relationship between the degree of significance of the signal and the slope angle of the line characterizing the relationship of the reaction time to the quantity of information perceived by the individual may be used as a quantification of such particularly psychological phenomena as the subjective relationship of the individual to the signals operating on him.

A test of this assumption revealed that for three different degrees of significance there were sharp changes both in the reaction time and in the rate of information processing. /103

Fatkin, L. V.: "General Concepts of the Information Theory and Their Application in Psychology and Psychophysiology," in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology], Moscow, Moscow State University Press, 1964, pp. 24-41.

This paper analyzes works devoted to the study of the rate of processing of information by an individual and indicates the difference in the

quantitative determination of "transmission capacity" in man, based on the data of various authors; values from 0.7 to 1,200 binary units per second are given.

Bibliography of 20 items.

Shekhter, M. S.: *Psikhologicheskaya Problema Uznavaniya,* [Psychological Problem of Recognition]. Moscow, "Prosveshcheniya" Press, 1967.

This monograph is devoted to a consideration of the psychophysiological and physiological characteristics of the formation and function of the recognition process. Particular attention is devoted to an analysis of the formation of the mechanisms of simultaneous (instantaneous) recognition. Special emphasis is placed on the fact that an individual achieves virtuosity in recognition which is based not on actual (conceptual) distinctive features but on qualitatively different aspects; in the course of training, an individual is modified to utilize perceptive (superficial) features which /104
cannot be called significant from a traditional viewpoint.

The book contains considerable experimental material.

Konopkin, O. A.: "Rate of Information Acquisition by Man and Cognitive-Derivative Regulation of Human Activity," in the book: *Sistema "Chelovek-Avtomat",* [The "Man-Robot" System]. Moscow, "Nauka" Press, 1965, pp. 119-127.

The acquisition of information by man as one of the forms of arbitrary cognitive activity. The rate of acquisition is determine not only by the biological nature of the individual (level of training, age, sensory differentiation, degree of compatibility of signals and reactions, physical intensity of signals, etc.) and not only by the external medium (the rate of appearance of the signals, probability of their appearance), but also are regulated cognitively-arbitrarily by the individual.

The paper contains a description of an experimental investigation which proved the position of the author concerning the act of regulation of the process of information acquisition through the activity of the second signal system.

The first group of experiments demonstrated the dependence of the reaction rate not simply on the rate of input of signals but on the realization of the rate. In the case of a warning concerning the rate of input (3.0, 2.0, 1.5, 1.0, 0.75 seconds), the first reactions of the subjects in experiments with higher rates turned out to be shorter than the reactions in experiments with a decreased rate. At the same rate of input of signals (1.5 seconds) and /105
a false warning (in one case, of a one second rhythm and in a second case of a two second rhythm), in the first case the reaction time for all subjects turned out to be 10-27% shorter than in the second. Hence, there was a definite relationship between the reaction rate and the preliminary situation, the knowledge of the subjects about the conditions of the experiment. The author suggests that in this case where dealing with a regulating (tonic) effect of secondary-signal stimuli on the physiological conditon of the functional structures corresponding to the experimental activity.

When using the rate without providing information until the subject has noted a change in the rhythm, there were no changes in the reaction time. If the changes in the rate took place during a single test, the subjects resorted to working out a cognitive strategy: the subject, for example, set up the problem of reaction as if the rate were always equal to one second; in this case, when the one-second rate was replaced by a three-second rate, the reaction changed by a total of 5%. With a strategy of guessing the moments of change in rate, there were considerable differences in the reaction rate.

On the basis of these facts, it was proposed that the rate of appearance of the signals influences the rate of reaction through the means of a cognitive-arbitrary moments of human activity and the working level of the physiological functional system, ensuring the activity, regulates the strategy of the activity adequately.

A second group of experiments was devoted to the probability of appearance /106
of signals. The probability of appearance of signals, viewed in a number of papers as the basic factor in the time of reaction, is (like the rate of appearance of signals) a condition of activity such that it is recognized by the subject and finds a reflection in the strategy of his activity.

Experimental data are presented which indicate the following:

1) The reaction time is independent of the probability of the signals if the subjective model of a probability ratio of the signals does not correspond to the objective statistical structure of their series. The probability of the signal may determine the "subjective probability" for the individual and the reaction time only to the extent that the probability can be found and finds an adequate reflection in the subjective concepts of the individual.

2) Even if the individual is familiar with the statistical structure of a series of events, the probability of the event, the stimulating information still does not determine the reaction time. The goal-directed nature of human activity is a common feature which is specific for human activity as the cause of limitations that are imposed on the dependence of the reaction rate on the stimulus information. The activity of the receiving process for information consists in the act of utilization of available knowledge concerning the conditions of activity, the cognitive structuring of one's activity in response to these problems.

Thus, in experiments with signals having different probabilities (0.50; 0.30; 0.15; 0.05), almost all of the subjects gave various signals different orders of significance, regardless of the previous warning given regarding the equal significance of all of the alternatives. /107

For the same problem (maximum speed and accuracy of all reactions) and equal probability relationships of the signals, the subjects will formulate their strategy differently. In some cases information was directed to signals with high probability and in others increased significance was allotted to slightly probable signals. Depending on the subjective interpretation of the probability characteristic of the signals, the results of the experiments showed variation.

In conclusion, it is determined that a different type of external determination (including instruction) does not determine directly the results of activity, and its action is disrupted by the cognitive attitude of its activity

through programming and regulation by the individual of his activity according to the input of information.

Gallay, M. L.: "The Problem of Criteria for Activity of a Human Operator," in the book: *Problemy Inzhenernoy Psikhologii*, [Problems of Engineering Psychology]. Leningrad, 1965, Second edition, pp. 78-83.

The article deals with the problem of the necessity of working out a well-founded system of criteria for evaluating the activity of an operator. It discusses the limitations of using for evaluation the "velocity" characteristics of an operator, the incorrectness of the opinion that the reaction rate reduces the effectiveness of the activity of a pilot or cosmonaut, controlling high speed aircraft. From this standpoint, a criticism is made of the finding /108 that was presented in the work by V. A. Yegorov and stated that the "carrying capacity for pilots flying in high-speed aircraft is higher." The author feels that the question here is not the speed of the aircraft but the fact that the pilot of a "faster" aircraft, as a rule a single-seater, has work that is more universal and more diverse.

The problem is posed as to the reliability of the activity of the operator and the author considers it incorrect to link it to the transmission capacity of the individual: the reason on the basis of which the pilot may not be able to handle a complicated situation lies not in the insufficiency of transmission capacity but elsewhere. The pilot rapidly "makes a diagnosis", but varies as far as "writing out the prescription" is concerned. It is precisely this aspect of activity which must be studied and in greater detail.

The article closes with a discussion of the necessity of studying the characteristics of training an operator.

Bibliography of 4 items.

Gippenreyter, Yu. B.: "Experience in Experimental Investigation of the Work of the Visual System of an Observer," in the book: *Inzhenernaya Psikhologiya*, [Engineering Psychology], Moscow, Moscow State University Press, 1964, pp. 192-230.

The article presents the results of experimental studies of the work of the visual system of an individual performed on the basis of simulation of certain aspects of the activity of the observer and the conditions for input of information on certain indicator devices. The principal method of investi- /109
gation was recording of eye movements.

1) Study of temporal parameters for the process of observation and identification of an object in the visual field was conducted on the basis of measurement of latent periods of establishing movements (glances) of the eyes upon the appearance of signals in various parts of the field of vision, and also time-and-motion study of the complex motor reaction with passage of time expended in observing the signal, direct in the eyes, "central switching" and executive motion.

The results of the experiments.

The latent period for eye movement (t_1) reveals a dense distribution of indices on the basis of individual directions relative to the center (fixation point) in the absence of a predominant value for any one of the directions. A slight increase in the latent periods of eye movements was observed with an increase in the distance from the fixation point to the point of appearance of stimulus. The average value for the latent period for the eye movement increases within limits from 230 msec with an amplitude of movement of 10° to 290 msec at an amplitude of 40°.

Measurement of the average duration of eye movements (t_1) with different amplitudes give the following results:

Amplitude of glance in degrees	10	20	30	40
Duration of the glance in msec.	60	70	90	100-120

The time of the motor reaction (t_4) turned out to be equal to 13 msec. Calculation of the total time of the reaction T of times t_1, t_2, t_4 gave the average time of delay and central switching (t_3). In the case of "fast" /110
subjects, it was equal to 50-150 msec, while for "slow" ones it was 360 msec.

Hence, the study revealed that individual differences in reaction time are governed by the time of the central branch of the complex reaction. The author dealt with the problem of working or operative field of vision, within whose limits conversion of visual information is accomplished simultaneously and the dimensions of which exceed the dimensions of the area of central vision.

2) Investigation of the characteristics of the function of the visual system under the conditions of uniform multiple objects (in the situation of selecting a signal from a combination of signals of the same type). The general structure of the macromovements of the eyes has characteristic features as a function of the conditions of the problem: there is a "logic" to the movements which corresponds to the object and the nature of the problem in question.

Results of the experiments.

During the fixation time of the point located at a distance of 10, 20, 40 or 60 minutes of angle from other similar points, the eye was in a state of continuous movement, during which drifting and glancing could be clearly seen (the eyes drifted to the sides and the glances consisted of correct movement). These two forms of movement ensure that the eyes remain in an area which consists of 14 (regardless of the density of the object). The development of an error in fixation is associated with the drifting "crawl" of the eye, which was not corrected by glances.

In experiments with tracing lines on a uniformly striped object, the average error of tracking at a density of 10' amounted to 6.5', at a density of 20-22', at densities of 40' and 60' there were no errors. The tracking /111
time at a density of 10 amounted to 14 seconds on the average and to less than 1 second at a density of 60. The amplitude of the eye movements depended on the density of the object as follows:

Density of the object in minutes of angle	5	10	20
Amplitude of glances in degrees	1-2	2-5	7-10

One of the principal results felt by the author to be the development of the fact of regular development of errors at certain densities of objects: the regular development of errors is observed at densities of 10-15'; unreliable and stressed function is observed at densities from 10-15' to 30-40' and error-free operation is observed at 40' and more.

3) The data obtained in the second experiment were checked under conditions of computation of signalization with large numerical tables. Previously, the conditions for effective work were investigated as shown in the table below.

TIME AND ERRORS FOR TRACKING FOR VARIOUS DENSITIES AND LENGTHS OF OBJECTS

Length of Object in Degrees	3		5		10		20		30	
Density of Objects	Time in sec.	% of err.	Time in sec.	% of err.	Time in sec.	% of err.	Time in sec.	% of err.	Time in sec.	% of err
10	0.8	0	1.5	0	2.5	10	5	25	10	40
15	0.3	0	0.4	0	0.8	0	1.8	15	2.5	25
20	0.2	0	0.3	0	0.8	0	1.5	0	2	10
30	0.2	0	0.2	0	0.4	0	0.8	0	1	0

On the basis of a preliminary experiment, conclusions were drawn regarding the existence of a particular area of the visual field within whose limits the function of the eye was characterized by "single action", following movements and their accuracy, this zone was called "the operative field of vision". /112

For the basic experiment, the authors selected tables whose dimensions and density allowed simultaneous examination of the stroke elements and therefore the following combinations of density and size: 15' -- 5°, 10' -- 3° and 20' -- 7°. The results are reflected in the table.

Density in Minutes	Angular Size in Degrees	Time of Searching for one number in sec.	% of error
10	3	6.9	1
15	5	5.6	2
20	7	6.0	2

With a long period of operation (about 2 hours) without interruption and seeking of 1,400 numbers, there was a considerable stability of the results in comparison to the average values for each hundred displays.

As a result of this series of experiments it was found that within the limits of the operative field of vision it is possible to have single-action and precise visual action and that the magnitude of the operative field depends on the density of the uniform object (at a density of 10' -- 3°, 15' -- 5-7°, 20' -- 10-15°).

4) The detection of the limiting size of the field within which recognition of objects is possible and experimental investigation of the cognitive function of vision can be tested. As a result of the work, it was concluded that there is an operative field of vision which is associated with the mechanism of the eye as a multichannel input. The dimensions of the operative field are considered as functions of many variables, the most important of which are those factors associated with the establishment and shifting of the attention, the nature of the visual problem, characteristics of the object and especially its spatial properties. /113

Bibliography of 24 items.

Oshanin, D. A.: "The Role of the Operative Sample in the Determination of the Information Content of Signals," *Voprosy Psikhologii*, No. 4, pp. 24-33, 1969.

The process of information conversion is viewed as an objective act that is performed with the aid of special operative images intended for this purpose. Experimentally it was proven that the processing time cannot be unambiguously derived from an abstract amount of signal information calculated on the basis of Shannon's formula or in some other fashion, but must be determined as a concrete specific of the process of coordination of the signals with image information.

The article describes the results of three series of experiments each of which differ not only in the quantity and the probability of the structure but also the mutual arrangement of positive and inhibiting bulbs, making it

possible to structure the operative image differently. The dependence of the reaction time on the possibility of increasing the information was demonstrated by establishing spatial relationships between the informative points.

Bibliography of 11 items.

Frantsen, B. S., Yegorov, V. A. and A. L. Kostyuk: "The Problem of the Nature of the Psychic Image in Flight Activity," *Voprosy Psikhologii*, No. 2, pp. 71-78, 1967. /114

The characteristics of the function of an operator are viewed by the authors in conjunction with the fact that not only are additional branches connected between the executive organs and the object of the work but that a technical branch of the communication channel which transmits information regarding the state of this object is connected between the sensory input of the individual and the final object of its action.

The question of the desirability of developing the image of an object to serve as a means of controlling an object is discussed. The idea is expressed that the regulating psychic object in the process of training must not be a picture of the object, but a picture of the instrument panel.

The stages in the formation of acclimatization to pilotage are discussed. It is only at the beginning of training that the student, before reacting to the changes in the readings on the instruments, must imagine the actual nature of the change that is taking place. In the course of automation of habit, the motor reactions begin to predominate in response to the changes in the readings of the instruments without thinking of the spatial nature of the position of the aircraft.

However, in certain situations in flight, some test pilots may develop a spatial image of the aircraft. Such conditions are unusual and abnormal, and they involve a failure of agreement between the running prediction and the activity; disruption of the accustomed algorithm for work and the development of new logical conditions apparently requires a more complex analytical-synthetic activity of the psyche. /115

In conclusion, the authors mention the possibility of control activity without construction of a direct image of the object under regulation.

Bibliography of 9 items.

Section 5 - The Man-Machine Problem /116

The statement of the man-machine problem in space has to do with the necessity (1) to work out the principles for distribution of functions between man (the crew) and machine; (2) to determine the characteristics of the human operator in space flight and (3) to work out the requirements for systems of indication and control which will be optimum from the standpoint of a human being [8, 25, 80, 22].

There is no disagreement in the literature regarding the role of the human being in a control system for a spacecraft. The individual is assigned the role of the dominant branch of the control system, checking the operation of the system, correcting its errors, assuming responsibility for decisions and controlling the craft under conditions that were unforeseen in the program or in the event of failure of automatic machinery [23, 45, 26].

The man-machine problem is primarily a problem of the optimum distribution of functions between the automatic system for control of the spacecraft and the cosmonaut himself. At the present time, this problem has two aspects: the technical (pragmatic) and the human (psychological and psychophysiological). The first aspect proceeds from the viewpoint that the inclusion of a human being in a control system for spacecraft simplifies it, makes it cheaper and more reliable [25, 22, 23, 45]. The pragmatic approach to the distribution of the functions determines a need to free the man from "excess" work involved in control, and limits him to control functions [13], "saving" him only for work under those conditions in which the automatic mechanism is powerless. The second aspect, which takes into account the technical requirements proceeds from the necessity for evaluating the state of the individual who must carry out the tasks of an operator, especially the function of the back-up branch in the event of failure of the automatic machinery. The fact is that the individual can completely retain his working ability only in the event that he has the ability to be active not on occasion but during the entire working time [60, 76, 86]. Hence, the distribution of the functions must allow not only for the practical necessity of the human being's participation, but also the dependence of his working ability at every moment on the

/117

planned activity. The relative freedom from activity of the individual demobilizes him, makes it difficult for him to carry out effectively the function of manual control in the event of failure of the automatic machinery [76, 36]. It is obvious that for an optimum distribution of the functions it is necessary to take both aspects of the problem into consideration.

The characteristics of the cosmonaut as an operator have been discussed in [45, 80, 26, 24, 3]. Several changes in the characteristics of the operator under the influence of space flight factors have been noted [45, pp. 134-136], [26, pp. 146], [3, p. 102], as well as the dependence of the characteristics of the cosmonaut on the characteristics of the indication and the control elements [80, p. 141], [26, p. 144, 145], [24, p. 148].

On the basis of the work that has been done in space, we are forced to conclude that the characteristics of the cosmonaut are similar to the characteristics of any operator of a control system who is placed in unfavorable physical and psychologically complex conditions of activity. Hence, the necessity for particularly careful development of engineering-psychological requirements for systems of indication, signalling and control of spacecraft [8, 23, 80, 24].

Articles [4, 56, 92] discuss various general aspects of the human operator: the complexity of the motor branch of his activity [56], certain mechanisms of attention [92], the stochastic nature of human activity, requiring consideration of random errors on the part of the operator in the planning of systems [4].

In working out the requirements, it is necessary to take into account both the unfavorable physical effects of space flight factors and the psychological complexity of the conditions of activity of the operator in automated systems of control for spacecraft. In particular, it is necessary to ensure readiness to act in the event of failure of automatic systems, taking into account the fact that the preceding period has been characterized by monotony and relative inactivity by the operator [76], absence of important feedback afferent impulses so important for rapid intervention in control with the motor analyzer [34], that the activity of the cosmonaut will

take place against an unfavorable emotional background and possibly with a lack of time.

Engineering-psychological requirements for informational models and a working area for the cosmonaut have been discussed in [23, 86, 34, 61, 35, 40].

The abstracts of papers that apply to the man-machine problem appear on pages 129-159 and also in Sections 1, 3 and 4.

Volynkin, Yu. and B. Denisov: "Psychology and Cosmonautics," *Meditsinskaya Gazeta*, 18 June, No. 49, pp. 2212, 1963. /119

A number of problems are discussed which touch on the study, and a general estimate of environmental factors and their preliminary influence on man is given, and basic problems of engineering psychology for space flight are discussed.

- Study of the possibilities of man as the principal branch of the control system;

- Analysis of cosmonaut activity;

- Adjustment of the work area to the needs and possibilities of cosmonauts;

- Standardization of cabin equipment;

- Development of means of training the crew.

Denisov, V. G.: "Some Aspects of the Problem of Combining Man and Machine in Complex Control Systems," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology], Moscow, USSR Academy of Sciences Press, 1962, Vol. II, pp. 54-67.

The article deals with the functions of a human operator in a complex control system. In the opinion of the author, they amount to a compensating tracking of many indicators, control operations to monitor the values of parameters being regulated, mathematical and logical analysis of information coming from devices and signal sources, generalization of the results of monitoring and comparison of them with the operating schedule, development of /120

solutions involving the control of an object and realization of this solution through control organs by a means of application of appropriate effects to them, as well as detection and immediate liquidation of emergency modes of operation of the object.

The article discusses the general requirements for indication and signalling:

1) Rapid stimulation of the sense organs and analytical systems for information. The article mentions the relativity of the concept of value of information, the dependence of the level of value of information on the ability of the operator to understand and use it. The value of information is determined as an increase in the probability of achievement of a goal for which the information is being collected. From this standpoint, there is no complete concept of the quantitative significance of information in the statistical sense and its qualitative meaning. To satisfy the first requirement in working out a concrete system for manual control, it is necessary to determine the relationship between the quantitative and qualitative parts of the information.

2) Ensuring the minimum frequency of turning toward the instruments during control. Discreteness of turning toward the instruments must be in agreement with the frequency of the change in the regulator parameter being measured by the instrument. An increase in the discreteness of utilization of the device may be achieved by using devices which make it possible to determine not only the values of the parameters but also the first and second derivatives by introducing automatic regulation of the parameter or by using some sort of audible "blower".

3) The requirement of ensuring a rapid and error-free determination of the readings. This has to do with the shape of the face of the instrument. General engineering-psychological rules are presented for the shape and location of the instruments. /121

4) The requirement for speeding up the generalization of information and the making of decisions, which is accomplished by introducing command (director) control devices.

5) The requirement for ensuring a direct link between the controlling action and its result, which is carried out by using inertia-free devices, and also by matching the direction of movement of moveable indices on instruments with the direction of movement of control organs.

Bibliography of 5 items.

Denisov, V. G.: *Kosmonavt Letayet .... Na Zemle*, [The Cosmonaut Flies.... On the Ground]. Moscow, "Mashinostroyeniye" Press, 1964.

This is a book written from the popular-science standpoint. It is devoted primarily to an examination of the methods of simulating certain space flight factors for the training of cosmonauts.

As far as the man-machine problem is concerned, the section "Man and Robot in Space", pp. 17-35, is particularly interesting, and is devoted to a discussion of certain general problems of the interaction of man and machine in space flight.

The necessity for the direct participation of a human being in space flight is determined by the fact that man is the most important organized and most reliable branch, so that he can act in a greater variety of ways, /122 taking action which has not been prepared for in advance under the most difficult flight conditions. In the view of certain advantages of robots (rapidity of action, multichannel capacity, ability to carry out monotonous work for an unlimited period of time, etc.), they can carry out only that which man has commanded them to do and according to those algorithms which have been worked out for them.

Mention is made of the necessity for an interaction between man and robot. The optimum interaction is based on a rational distribution of functions between man and machine.

Mention is made of certain specific conditions for the work of a cosmonaut: long flight duration, slow reaction of the craft to controlling influences, considerable stability of the flight schedule in orbit, the unusual nature of a number of tasks to be performed, change of the gravitational field over wide limits, closeness of the environment, separations from accustomed

social medium, lack of time in emergency conditions, limitation of functioning of motor apparatus. Inasmuch as the human operator as a branch of the control system has a discreteness for signal input which is 0.38-0.44 seconds, he can act as an amplifier, integrator and differentiator only for input signals which lie in the frequency range from 0 to 0.5 Hz.

The article emphasizes the necessity of studying the psychological possibilities of man in order to work out requirements for information and control systems. The importance of the engineering-psychological direction of the work is governed by the fact that the reliability of the operator's work depends on the design of the working area. /123

Isakov, P. K., Popov, V. A. and M. M. Sil'vestrov: "The Problem of Human Reliability in Control Systems for Spacecraft," in the book: *Problemy Kosmicheskoy Biologii*, [Problems of Space Biology], Moscow, "Nauka" Press, 1967, Vol. 7, pp. 5-10.

This is the text of a paper delivered at the Second International Symposium on the Basic Problems of Human Life in Space (Paris, 14-18 June, 1965).

It deals with the problem of including man in the control system of a spacecraft, and mentions the necessity for a careful design of conditions which will apply to the human being and the automated systems. Inclusion of a human being increases the reliability of the control system of spacecraft, both due to the replacement of automatic machinery and due to the ability to repair faulty elements.

It is pointed out that the "operator-spacecraft" system is a closed multicontour system, and the individual can act the role of logical branches, measuring parameters of the control process, amplifying, integrating and differentiating branches, devices for formation of control effects, etc.

The difference in certain characteristics of working operations on the ground and in space is pointed out, in particular, the slowing down of the speed at which effects are carried out (B. B. Yegorov, when working in space with medical apparatus, spent 1.5 to 2 times more time than he did on Earth).

The insufficiency of the data obtained on space flights for study of reliability and effectiveness of the work of the cosmonaut is confirmed and mention is made in this connection of the necessity of simulating the work of the cosmonaut on the ground. /124

In controlling the spacecraft, both situations of excess time and situations with a lack of time may develop (during the docking, rendezvous, return to the dense layers of the atmosphere, landing, and other stages). In the first case, the individual can disassociate himself from the control of the process, causing deterioration of its characteristics, while in the second he can observe the transmission of signals and delayed reactions.

When simulating the work of the cosmonaut, certain characteristics of human activity were defined; during the control process for the spacecraft, reading the instruments which characterize the state of the cabin environment required times from 2.2 to 3.1 seconds, with the average time for perception of light signals varying from 0.8 to 1.2 seconds, and the accuracy of control depending on the information model, and the placement of the indicated signals. The accuracy of control on the basis of the vertical channel was found to be lower than the accuracy of control for the lateral channel (from 1.6 to 2.2 times depending on the type of indication: matching of two circles, controlling the position a spot on a cathode-ray tube, maintaining the symmetry of a circling symbol within the limits of a cathode-ray tube).

The dependence of the perception time for signals corresponding to control processes on the degree of deviation of the controlling index from the given position is discussed. With a deviation of more than 4 mm, the average time for determination is equal to 0.9 seconds, for the deviation of 1 second /125 it is equal to 1.2 seconds. With a rate of movement of the image that is greater than 1 mm/second, the time for the determination of the sign of the derivative of deviation amounts to 1 second. With a lower velocity, this time increases and at a rate of 0.1 mm/second it reaches 4.2 seconds.

It has been established that in distributing the functions of control between the crew members, the quality of control is improved by a factor of

1.5 (with control of 8 coordinates of the process) in comparison with the work of a single operator.

The study of the quality of the activity under the influence of certain interference gave the following results: 1) in creating the experimental illusion of rolling by stimulating the vestibular analyzer with direct current (from 2 to 5 μA), the perception time for paravisual signals was increased by 2 to 3 seconds and the coordination of the controlling movements was disrupted. 2) Under the influence of a 90 db noise and a temperature of 40-45°C after 3-4 hours of control, the quality of the latter deteriorated by 1.2 times. 3) The effect of isolation and hypodynamia deteriorated the quality of control by 1.5 times during the first few days and then (beginning with the third and fourth days) the quality of control was restored to normal. A similar tendency was observed on real flights. 4) When the load on the operator was increased by additional work, the quality of control of movement in space of the craft deteriorated by 1.7 times.

In conclusion, it is mentioned that the effect of method of evaluating the reliability of a human being in control systems for spacecraft consists in a wide utilization of modelling of the dynamics of the control process and the condition of the operator.

Tochilov, K. S.: "The Problem of the Reliability (Working Ability) of a Human Being in Control Systems," in the book: *Problemy Inzhenernoy Psikhologii. Materialy I Leningradskoy Konferentsii po Inzhenernoy Psikhologii, iyun', 1964,* [Problems of Engineering Psychology. Materials of the I Leningrad Conference on Engineering Psychology, June, 1964]. Leningrad, 1964, pp. 14-15. /126

The problem of human reliability is equated (from the psychophysiological standpoint) with the problem of working ability. For a trained operator, the problem of developing high degrees of reliability during a maximum time interval is achieved by the optimum relationship between the magnitude of the stimulus (system of signals) and the duration of their action.

Both a small and large magnitude of stimulus are characterized by a smaller duration of stable working ability than the average. Inasmuch as progress in remote control consists in an ever-increasing application of

automation, freeing man from direct activity, special attention must be paid to a small level of stimulus at which there is a state of operative rest, when the individual intervenes in control in extreme, emergency instances against the background of extreme responsibility. This requires maintenance of a high functional level for immediate reaction. The absence of external stimuli for long time intervals, especially those stimuli which convey information, reduces the functional level of man.

Oshanin, D. A. and V. F. Venda; "Some Methods for Increasing the Effectiveness of the Work of an Operator in 'Man-Robot' Systems," *Voprosy Psikhologii*, No. 3, pp. 23-36, 1962. /127

The article deals with the activity of an operator in automated control systems. An important characteristic of the activity of an operator under normal conditions, when the control function is carried out by automatic machinery, is indicated by the fact that information regarding the working parameters of the system which does not require responsive reactions so to speak loses its signal function and in addition has a very monotonous nature. Under these conditions, there is a constant decrease in the attention of the human being which leads to a decrease in his reliability. It is pointed out that effective intervention of a human being in control in the event of failure of automatic machinery involves the presentation of information. Automation which causes the relative inactivity of man demobilizes him and in order to go from a passive state to complete mobilization of all his psychic resources the operator requires information about the previous history of the process.

Finally, the need for joint intensification of technical sciences and industrial psychology for increasing effectiveness of the work of an operator is emphasized.

Zavalova, N. and V. Ponomarenko: "Principles of Selecting Optimum Coding of Emergency Signals," *Tekhnicheskaya Estetika*, No. 10, pp. 24-26, 1969. /128

Emergency signals are viewed as specific stimuli requiring the operator to switch to a new form of activity, taking place against an unfavorable emotional background. To ensure reliable action on the part of the operator

in an emergency situation, the authors propose that the design of signals provide, in addition to the surprise effect of the signal, a timely understanding by the operator of the significance or cause of the event. The conditions for providing an operator in an emergency situation with certain unambiguous information regarding what has taken place are discussed, and data are presented on the increase in effectiveness of activity by an operator as a result of agreement of the characteristics of the signal with the requirements of the operator in a concrete situation.

Popov, V. A., Rozanov, Yu. A. and M. M. Sil'vestrov: "An Information Model of the Dynamics of Movement and Spatial Orientation of a Cosmonaut Outside a Spacecraft," Paper delivered at the 17th International Astronautical Congress held in Madrid, 9-15 October, 1966. Moscow, 1966.

This article deals with the problem of ensuring movement and orientation, cosmonaut outside the spacecraft. Inasmuch as sensory information is limited in a state of weightlessness, it is necessary to design special technical devices which will compensate for this limitation. Mention is made of the /129
fact that the individual system of control must ensure automatic stabilization on the angular velocity of the cosmonaut near zero value.

The cosmonaut must obtain information regarding the change in coordinates of the control process of orientation and the movement by means of observation of changing values of the visible shape of the craft and on the basis of its movement in the field of vision with a fixed position of the head relative to the trunk; additional information is obtained by the cosmonaut from the positions of the Earth, Moon and stars.

The dynamics for control of movement by the cosmonaut relative to the spacecraft in deep space has been studied on a simulation stand, which consists of a continuously operating computer, a model of the power supply with elements of the manual control and cathode ray oscilloscope systems. A simulated picture of the ship moves and changes its dimensions on the screen of the cathode-ray tube in accordance with the control dynamics. The problem of the operator consists in "going away" from the craft to a distance of 40 meters and then returning.

Results of the study.

In the absence of instrument information relative to the distance and speed of approach, the operator "departed" from the craft to a distance of 41 meters on the average, with a mean square deviation of 4 meters in range and 15 cm/ second in speed. When he received instrument information regarding relative range and speed, the operator departed from the ship to an average of 40.1 meters with a mean square deviation with regard to range of 0.2 meters and a speed of 2 cm/second.

For the operation involving his return to the craft, the cosmonaut was required to have information about his angular position relative to the direction of the craft, the angular velocity of the line of sight, the relative distance and rate of approach. The angular velocity of the line of visibility was determined by the pilot on the basis of obervation. /130

The experiment showed that from a distance from 40-50 meters the pilot could return to the craft with the absence of instrument information regarding distance and speed of approach and the angular velocity of the line of sight. However, in the presence of information regarding range and distance, the average values for speed of return were decreased by more than two times. Spoken advice also improved these characteristics: the rate of return was reduced by a factor of 1.5.

Retention of spatial orientation is provided by conditional orientation relative to the system of reference corresponding to the coordinates of the axes of this craft. To determine the angular position of the craft relative to the cosmonaut, it is desirable to use special marker elements (vertical and horizontal luminous strips) mounted on the craft. To distinguish one marker from another, one of them must flash.

The experiments showed that the markers provide sufficient accuracy in determining the angular position of the craft if they have an angular dimension (lengthwise) which is at least 5-7 and if their brightness is not less than twice as great as the background brightness.

In conclusion, it is stated that the individual system for control of movement for the cosmonaut must include motors which allow the cosmonaut to

rotate relative to three mutually perpendicular axes and permit him to move linearly along three axes of the coordinates, control elements, systems of automatic stabilization of angular velocity and an information model which will ensure the cosmonaut of having information regarding his spatial position relative to the craft and the parameters of its movement, with the information /131
regarding relative range and velocity of approach being supplied by instruments.

Denisov, V. G., Onishchenko, V. F. and V. I. Yazdovskiy: "Psychophysiological Possibilities for Cosmonauts in Controlling a Craft and Its Systems (Engineering Psychology)," in the book: *Kosmicheskaya Biologiya i Meditsina. Mediko-Biologicheskiye Problemy Kosmicheskikh Poletov*, [Space Biology and Medicine. Medico-Biological Problems of Space Flights]. Moscow, "Nauka" Press, 1966, pp. 401-444.

The principal content of the cosmonaut's profession consist in controlling the craft and its systems, including the research complex. In the control system for the spacecraft, the operator actually does not control the devices and the mechanisms but rather devices which control the condition of the latter.

The problems of engineering psychology in cosmonautics are discussed. The following problems are pointed out: analysis of the functions of the operator in control systems, distribution of functions between the operator and the machine, study of the rational connection of the operator with the technical elements, comparative study of the possibilities of the operator and the machine, study of the characteristics of the accuracy, speed and reliability of the effects of the operator and machine, as well as a determination of the reliability and effectiveness of the systems.

On a general plane, the possibilities of man and machine are compared, an emphasis is placed on the increase in reliability of the control systems of a spacecraft with an optimum combination of the possibilities of an operator and the characteristics of a control system. /132

It is pointed out that engineering psychology is studying the characteristics of the sensory input of the operator, the volume of information

received by the operator per unit time, the best forms of encoding the information, the nature of the controlling actions of the operator on the control system.

Certain criteria for evaluating control systems with participation of the operator are discussed. In addition to the indices of the dynamics of the control process (transitional functions, their nature, the time of the transitory process, errors in various modes), the criteria for evaluation include estimates of the emotional stress on the operator, determined on the basis of data from complex recording of physiological functions. It is pointed out that with a uniform quality of work the control under the most difficult conditions is accompanied by an increase in the high-frequency rhythms in the EEG relative to easier work. The reliability of the operator can be evaluated on the basis of indices of the bioelectric activity of the cortex, bioelectric activity of the muscles, magnitude of the amplitude of spontaneous oscillations in the GSR, the values for the frequency of cardiac contractions and respiration. It is most advantageous to record the following components of the EEG frequency spectrum: delta-two-rhythm, delta-one-rhythm, theta-rhythm, alpha-rhythm, beta-one-rhythm, beta-two-rhythm, beta-three-rhythm. For analyzing the EEG, a method is recommended in which it is possible to consider the absolute value of the integral value of each rhythm.

The results of an investigation of the organs for manual control are presented: a three-channel contact handle and a keyboard panel. Table 1 shows /133 the results which indicate the advantages of control using a keyboard panel.

Table 2 shows the data for recording of physiological functions which also indicate the advantages of a keyboard control.

TABLE 1

Parameter	Control by Means of a Handle	Keyboard Control
Average time of orientation in relative units (relative to ideal control)	1.35	1.17
Average time for generalized error of angular position (degrees)	5.87	3.37
Average energy consumption (arbitrary unit)	15.40	11.90
Average number of erroneous actions in control during the process of the orientation cycle.	3.00	0.05
Average time for reading one indicator in the process of control, sec.	3.14	3.05

TABLE 2

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Parameter	Components of Encephalogram & Recording Conditions for Physiological Functions	Control With a Handle	Keyboard Control
Average indices of bioelectrical activity of the cerebral cortex (arbitrary units).	Delta-one and theta-rhythm (2-8 Hz)	33.5	34.3
	Alpha-rhythm (8-13 Hz)	31.4	30.2
	Beta-one and beta-two rhythm (13-30 Hz)	20.1	17
Average value of skin-galvanic reaction, after Tarkhanov, microvolts.	Before work	580	530
	During work	906	730
	After work	770	350
Average number of cardiac contractions per minute	Before work	78	78
	During work	89	82
	After work	80	80

The complexity of psychophysiological processes is mentioned, together with the impossibility of representing the transmission function of the operator by any single relationship, the impossibility of determining the "standard" transmission functions, typical for the majority of operators,

for certain conditions of activity. Emphasis is placed on such important characteristics of the operator as the fact that he can by means of training achieve a degree of similarity of his transmission function to almost any given value. The possibilities of the operator must be investigated with a sufficient number of laboratory and flight experiments involving a great many operators.

The average statistical characteristics of the operator are given as follows: the average values for the reaction time of man, together with certain general characteristics of vision, hearing and other analyzers.

Several characteristics are discussed which have been obtained in experiments performed under conditions resembling those aboard spacecraft: the time of determination of geographical coordinates was 7.7 sec; the time of perception of light signals varied from 0.8 to 1.2 sec; the acuity of visual determination of angular values amounted to 3 ; the resolving power relative to angular velocity with time of observation equal to 10 sec was 0.3 minutes of angle per second. It was found that with minimum friction in the support on which the subject was located, moving the handle "toward himself" and "away from him" required maximum effort to move the handle with simultaneous stabilization of the subject himself. The effectiveness of the effort applied was 27 times less for movements toward himself, 18 times less for movements away from him and three times less for rotational movements. With reduced gravitation, the muscular force of the hand decreased by 4-6 kg with an initial level of 45-60 kg and the accuracy of determination of muscular forces decreased. /135

The materials obtained during the flight of the crew of the "Voskhod-2" showed that in space flight the resolving power of the eye and acclimatization to carrying out certain programmed action is not subject to significant changes.

Emphasis is placed on the necessity for evaluating the activity of the operator through experimental study of his behavior and the characteristics of the operator in a concrete control system.

A possible system for training devices for preparing cosmonauts is discussed.

In conclusion, there is a discussion of the formation of professional habits in operators in controlling spacecraft and its systems. A descriptive /136
characteristic of working habits of the cosmonaut is given. An evaluation of the formation of habits is given under extreme conditions and with complication of working conditions.

Bibliography of 42 items.

Denisov, V. G., Zav'yalov, Ye. S., Kuz'minov, A. P., Sil'vestrov, M. M. and V. I. Yazdovskiy: "Problems of Engineering Psychology and Some Results of Investigations," *Kosmicheskiye Issledovaniya*, Vol. 2, No. 5, pp. 783-796, 1964.

The article contains a determination of the object of engineering psychology in space and three basic problems in working out systems for control of spacecraft:

- investigation of psychophysiological possibilities of an operator and a change in these possibilities under the influence of space flight conditions;

- imposition of requirements on control systems for spacecraft in order to match their characteristics with the capacity of the operator;

- development of methods and means of preparing cosmonauts for professional activity.

The general characteristics of the activity of an operator are given as a controlling branch in closed "cosmonaut-craft" systems and schematic diagrams of control systems with participation of the operator are presented.

A complex method is presented for evaluating a closed system consisting /137
of an operator and a ship, in which physiological criteria are used along with the method of cybernetics and the theory of information which provide engineering estimates.

The results are given for engineering-psychological studies on a simulation stand. Data are presented on the perception time of instruments (0.28-0.8 seconds), maximum reaction time to rapid signal sequences (0.25 sec with an interval of 0.57 to 2.91 sec between signals).

An analysis is presented of the characteristics of the conditions of activity of a cosmonaut aboard a "Vostok" type craft:

- complete automation of control processes, performance of control functions by the cosmonaut;

- slowing down of the reactions of the craft to the control actions.

Data are presented on the absence of a time limit (access time) in carrying out actions by the cosmonaut. The time required for determining geographical coordinates is given as 7.7 seconds, for determining the state of the environment in the cabin -- 2.2 to 3.1 seconds, for detecting light signals -- 0.8-1.2 seconds. Data are presented which indicate that the transmission of 5-6 light signals on one panel decreases the surprise effect of emergency signals and makes it necessary to place the signal panel according to its functional purpose.

General remarks are made concerning the design of the cabin. A theory is postulated concerning the difference between space flight and flight in an aircraft -- absence of a lack of time and a change in requirements for information at various stages of the flight. /138

Comparative data are presented on the dependence of the quality of control on the shape of the control organ (three-channel contact button and keyboard panel), the advantages of control using a keyboard panel are shown. The data from the experiment are listed in the table:

Name of Parameter	Handle	Keyboard
Avg. time of orientation in relative units	1.35	1.17
Avg. value of generalized error of angular position.	5.87°	3.37°
Avg. energy consumption in conditional lunits.	15.4	11.9
Avg. number of errors.	3.00	0.05
Avg. time for reading one indicator	3.14 sec.	3.05 sec.

It is stated that it is necessary to prepare the cosmonaut on the ground and handle problems of developing professional trainers. It is recommended that trainer systems be used which consist of complex, specialized and functional trainers.

Bibliography of 9 items.

Nefedov, Yu. G., Popov, A. K. and L. P. Salmanov: "A General Approach to /139
the Analysis of Activity Involved in Controlling Spacecraft," in the book: *Aviatsionnaya i Kosmicheskaya Meditsina, Trudy III Vsesoyuznoy Konferentsii (g. Kaluga, 10-13 Iyunya 1969 g.)*, [Aviation and Space Medicine, Transactions of the III All-Union Conference (Kaluga, 10-13 June 1969)]. Moscow, 1969, Vol. 1, pp. 330-334.

This report constitutes an attempt to develop the general principles for analysis of the control movements of a cosmonaut on the basis of an establishment of the dependence of the functioning of certain regulatory mechanisms of the brain on the technical characteristics of the control system. As the regulatory elements for explaining the operator activity of the cosmonaut, the concept of the "elementary regulating branch" is introduced into the work of the central nervous system.

"Elementary regulatory branches" were observed at the level of the micro- and macrostructure of the brain, and also in the function of the analyzers. A discussion of the operator activity of the cosmonaut from the standpoint of the "elementary regulatory branches" forming its base may be represented as their composition as a function of the order of astatism (n) of the object of control. The order of astatism of the control systems of a spacecraft usually does not exceed two, so that the cosmonaut in every concrete case must detect and handle no more than three parameters (amplitude, speed and acceleration) for any process under his control.

Multiple regulation is the result of joint operation of a number of interacting individual regulatory mechanisms.

Bobneva, M. I.: "The Problem of Human Reliability (Regular and Random /140
Deviations in the Work of an Operator)," in the book: *Problemy Inzhenernoy*

Psikhologii, [Problems of Engineering Psychology], Leningrad, 1965, Second edition, pp. 7-13.

Mention is made of the absence of a general approach to the problem of human reliability. In the opinion of the author, it is necessary to develop a common system of concepts within the framework of the problem of human reliability. Reliability is a global qualitative characteristic of behavior. "Reliability" is a characteristic which is distinct from all the others such as accuracy of activity, workability, "noise resistance", emotional stability, etc.

The article mentions that investigators of various aspects of reliable behavior have omitted discussing one of the most important facts, that of the stochastic nature of behavior, and it is precisely on this factor that the matter rests.

By reliability of man, we understand his ability to carry out given functions under given conditions and at a given time.

The author proposes defining the nature of failures and differentiating two types of failures: regular and random. The causes of regular failures may be determined and isolated in various ways. In practice, there is another type of failure which cannot be explained objectively by any known cause -- these are the random failures of the operator. It is precisely the random failures which constitute the greatest danger when an individual works with systems where his actions directly or indirectly affect the outcome of the entire system. Data on random failures indicate the stochastic nature of human activity; they indicate the insufficiency of the position of "macro-determinability" of human behavior. /141

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Levandovskiy, N. G.: "Experience in Experimental Determination of Senso-motor Structure of Activity," *Voprosy Psikhologii*, No. 6, pp. 42-54, 1959.

Control of machines through devices leads to considerable loads on the intellectual sphere. In addition, there is an increased load on the sensory and motor spheres.

This study is devoted to an examination of fractioned movements. All fine and exact production operations would be impossible without control over the corresponding fractioned movements. On an experimental basis, the author has developed special conditions for production and examination of fractioned movements. It is shown that inadequacy of the signals for additional correction leads to disruption of the visual image.

The reaction time of the fractioned variety is four times greater than the time for ordinary reactions.

Bibliography of 9 items.

Chuprikova, N. I.: "Neurophysiological Foundations of the Limitation of the Scope of Attention," *Voprosy Psikhologii*, No. 2, pp. 23-37, 1968. /142

The article is a description of experimental facts that promote the clarification of the neurophysiological causes that lead to the existence of the phenomenon of limitation of attention.

The following two positions are established: 1) in remembering visual stimuli, the excitability of the corresponding projections of the analyzer is increased relative to the excitability of its other points; 2) the degree of increase in excitability of each of the points in the analyzer, corresponding to projections of simultaneously manifested ones (remembered signals), decreases with an increase in the number of the latter. When the number of objects increases, to which the attention is direct simultaneously, there is a decrease in the local excitability of the analyzer; this decrease with a simultaneous increase in the number of points where it takes place unavoidably is reflected in the attenuation of the intensity of the attention in a deterioration of focusing of its foci and a deterioration of memorization of perceived objects. A hypothesis is suggested concerning the negative induction nature of the phenomenon.

Bibliography contains 36 items.

Zavalova, N. D. and V. A. Ponomarenko: "Some Problems of the Reliability of the Action of an Operator of an Automated Control System in the Event of /143

Failure of the Automatic Mechanism," *Voprosy Psikhologii*, No. 4, pp. 49-56, 1968.

The specific nature of the problem of human reliability, in the opinion of the authors, consists in the fact that for its solution it is necessary first of all to consider the characteristics of the actions of the operator under the most difficult conditions. From this, the critical moment for the study of the "psychology of reliability" in automated systems must be the process of transition of the individual from the control function to the manual regulation function in the event of failures that develop in the control system.

The article deals with characteristics of the activity of a pilot in automated flight: during the process of monitoring the automatic mechanism, the pilot is deprived of the flow of feedback proprioceptive impulses that he obtains continuously with manual control, which in addition to the visual signals inform him about the behavior of his machine. While the relative sensory deprivation of man in automated flight does not play a role in the correct operation of the equipment, it must not be omitted in case of failure of the automatic machinery and the necessity to compensate by improvement of visual information. This is especially necessary at the moment of transition from control to manual operation, when the difficulty of the actions of the pilot is made more difficult by the lack of time and the unfavorable emotional background.

Results are presented for an experimental study which shows that the absence of feedback proprioceptive signals during automated flight leads to a series of test movements at the time of transition to manual control, which /144 are undesirable from the standpoint of retaining the given flight regime. The use of a special visual additional indication of failure has been found to be effective only in the case when the indicator does not simply attract the attention of the pilot to the fact of failure but also facilitates the comprehension of the emergency situation and increases the information dependence of the instruments for manual control. In this case, there is a sharp drop in the quantity and duration of the non-advantageous test movements which are characteristic of the transition process to manual control.

It is emphasized that the effectiveness of signalling showing the failure of an automatic system is determined not by the surprised effect of the signal but the property of the signal to organize the action of the pilot in the event of failure of the automatic machinery and especially to select the information that is necessary for carrying out control movements.

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Lomov, B. F.: "Some Criteria for Evaluating Signals Transmitting Information to a Human Operator," in the book: *Problemy Inzhenernoy Psikhologii*, [Problems of Engineering Psychology]. Leningrad, Second edition, pp. 134-145, 1965.

The problem of the principle of construction of information models is discussed, with emphasis on the need for agreement of the model with the characteristics of the human operator. The steps in constructing an effective information model (from the standpoint of man) are discussed.

The starting moment for selection of the elements (alphabet of signals) /145
and the principles of their organization into informational models is the analysis of the represented medium; separation of the objects forming it (and processes) and their parameters. In addition, the number of possible states of each object is determined on the basis of each of the parameters and the probability of their development. During analysis, the total number of elements is determined which form the model and their information content, i.e., the total length of the alphabet is determined with which the operator will work.

In developing a method of coding, the question arises of an alphabet of signals such that it will be optimum for given concrete conditions. Mention is made of the familiar crisis using methods of information theory to determine the transmission capacity of man and the insufficiency of the formal approach to the study of psychic phenomena. Emphasis is placed on the necessity of a psychological study of the structure and dynamics of the operations involving reception and analysis of information. This operation includes: 1) search and detection, 2) differentiation, 3) identification, 4) decoding (interpretation).

The development of a method of encoding information is also a certain degree of organization of these processes.

The condition which is most common to the act of detection is the difference between the characteristics of the signal and the background. During the process of differentiation, the transmission capacity acquires maximum significance only when the difference reaches the values that exceed the threshold by a factor of 10. In solving problems of identification, the volume of information transmitted by means of a unidimensional stimulus is highly insignificant (not in excess of three binary units). Information on /146
the signal is increased in proportion to the logarithm of the number of its measurements. In acts of identification, the critical role is played by the ratio of the perceived signals to certain standards that are stored in the memory. The final step in the information collecting process is decoding. On the basis of observation, differentiation and identification of the signal, the operator must evaluate the status of the object being monitored, i.e., he must relate the signal to the object, transforming the perception of the former into the representation of the latter.

All the signals can be divided into two classes: signal-images and signal-symbols; the advantages and limitations of each class of signals are discussed.

Mention is made of the dependence of the transmission capacity on the problem posed to the operator. It is emphasized that in real conditions of activity, the operator uses a dynamic alphabet of signals: in transition from one operation to another, the alphabet changes. The importance of studying this dynamics in determining the principles of optimum coding and the necessity for examining the possibilities of using dynamic coding are discussed, i.e., signals such that they will change their characteristics in accordance with a logical operation of information input.

Bibliography of 32 items.

Zavalova, N. D. and V. A. Ponomarenko: "Psychophysiological Characteristics of the Activity of Man in Automated Control Systems," in the book: /147

Problemy Kosmicheskoy Meditsiny, [Problems of Space Medicine]. Moscow, 1966, pp. 173-174.

The specific feature of human activity in automated flight is the fact that executive functions are accomplished by the individual only in the event of failure of the automatic machinery and the pilot remains an observer during the normal flight regime. During the observation process, the individual is deprived of the feedback afferent impulses from the motor analyzer which are very important for effective control of an aircraft, and this complicates the transition of the pilot to active motor activity if it suddenly becomes necessary to intervene in control.

As the criteria for effectiveness of operation of the human being, time characteristics resultativity of action and physiological indices are employed.

Zonabend, F. M. and L. D. Chaynova: "Investigation of Perception of Cartographic Information," in the book: *Aviatsionnaya i Kosmicheskaya Meditsina. Trudy III Vsesoyuznoy Konferentsii (g. Kaluga, 10-13 Iyunya 1969 g.)* [Aviation and Space Medicine. Transactions of the III All-Union Conference (Kaluga, 10-13 June 1969)], Moscow, 1969, Vol. 1, pp. 244-246.

An objective method is suggested for selecting and evaluating the optimal characteristics of cartographic material intended for use aboard aircraft. The process of navigation consists of two parts, chart perception and comparison of the latter with a chart of the area; the perception process can be broken /148 up into 1) general perception of the chart, 2) cartometric operation and 3) perception and recognition of specific features.

Methods are suggested for investigating the mechanism of perception: electrocardiography, electroencephalography and recording of vocal responses. Use of EKG and EEG indicators has made it possible to determine the causes of easy and difficult perception and to carry out a quantitative estimate of the legibility of the material. It was found that the reason for the decrease in effectiveness of perception when density of symbols was increased on the chart is explained by two factors: a shortening of the fixation time and a decrease

in the number of eye movements, and it is precisely the latter which govern the flow of information. The dependence of effectiveness on the degree of excitation was determined on the basis of alpha-rhythm indices.

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